PORTLAND HARBOR RI/FS

PROGRAMMATIC WORK PLAN

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ADCP	Acoustic Doppler Current Profiler
AINW	Archeological Investigations Northwest
AOC	Administrative Order on Consent
ARAR	Applicable or Relevant and Appropriate Requirement
AWQC	Ambient Water Quality Criteria
BCF	bioconcentration factor
BEHP	bis(2-ethylhexyl)phthalate
bgs	below ground surface
BMP	best management practice
BSAF	biota sediment accumulation factor
BTEX	benzene, toluene, ethylbenzene, xylenes
CAD	confined aquatic disposal
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CGF	coarse-grained flood deposits and upper Troutdale Formation
COC	chemical of concern
COI	chemical of interest
COPC	chemical of potential concern
cfs	cubic feet per second
CRBG	Columbia River Basalt Group
CRD	Columbia River Datum
CSM	conceptual site model
CSO	combined sewer overflow
DDD	dichloro-diphenyl-dichloroethane
DDE	dichloro-diphenyl-dichloroethene
DDT	dichloro-diphenyl-trichloroethane
DEA	David Evans and Associates
DEQ	Oregon Department of Environmental Quality
DNAPL	dense non-aqueous phase liquid
DO	dissolved oxygen
DQO	data quality objective
ECSI	Oregon Environmental Cleanup Site Inventory
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
EROD	ethoxyresorufin O-deethylase
ESA	Endangered Species Act
FFA	fill, fine-grained facies of flood deposits, and Recent alluvium
FSP	field sampling plan
GLISP	Guild’s Lake Industrial Sanctuary Plan
GPS	global positioning system
GRA	general response action
HHRA	human health risk assessment
HPAH	high molecular weight polycyclic aromatic hydrocarbon
HSP	health and safety plan

ISA	initial study area
K_d	soil/water partitioning coefficient
K_{oc}	organic carbon partitioning coefficient
K_{ow}	octanol-water partitioning coefficient
LASAR	laboratory analytical storage and retrieval
LCRMA	Lower Columbia River Management Area
LNAPL	light non-aqueous phase liquid
LOAEL	lowest observed adverse effect level
LOEC	lowest observed effect concentration
LPAH	low molecular weight polycyclic aromatic hydrocarbon
LWG	Lower Willamette Group
LWR	lower Willamette River
µg/kg	microgram per kilogram
µg/L	microgram per liter
m	meter
mg/kg	milligram per kilogram
mg/L	milligram per liter
mya	million years ago
MOA	memorandum of agreement
MOU	memorandum of understanding
MS	matrix spike
MSD	matrix spike duplicate
MSL	mean sea level
MTCA	Washington Model Toxics Control Act
NPL	National Priorities List
NAPL	non-aqueous phase liquid
NAVD	North American Vertical Datum
NGVD	National Geodetic Vertical Datum
NOAEL	no observed adverse effect level
NOEC	no observed effect concentration
NPDES	National Pollutant Discharge Elimination System
NRC	National Response Center
NRDA	National Resource Damage Assessment
OSU	Oregon State University
OSWER	Office of Solid Waste and Emergency Response
ODHS	Oregon Department of Human Services
PACG	preliminary analytical concentration goal
PAH	polycyclic aromatic hydrocarbon
PBT	persistent, bioaccumulative toxin
PCB	polychlorinated biphenyl
PCP	pentachlorophenol
ppm	part per million
PRD	Portland River Datum
PRE	preliminary risk evaluation
PRG	preliminary remediation goal

PRP	potentially responsible party
PSEP	Puget Sound Estuary Program
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
RA	remedial action
RAO	remedial action objective
RCRA	Resource Conservation & Recovery Act
RD	remedial design
RI/FS	remedial investigation/feasibility study
RM	river mile
ROC	receptor of concern
ROD	Record of Decision
RPD	redox potential discontinuity
SAP	sampling analysis plan
SEA	Striplin Environmental Associates
SMA	sediment management area
SOW	Statement of Work
SPI	sediment-profile imaging
SPMD	semipermeable membrane device
SRM	Sandy River Mudstone
STA®	Sediment Trend Analysis®
STORET	EPA’s Data Storage and Retrieval System
SVOC	semi-volatile organic compound
TBC	to be considered
TBT	tributyltin
TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
TCDF	2,3,7,8-tetrachlorodibenzofuran
TM	technical memorandum
TMDL	total maximum daily load
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TRV	toxicity reference value
UCL	upper confidence limit
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VOC	volatile organic compound
WRDA	Water Resource Development Act

1.0 INTRODUCTION

This programmatic work plan describes the activities that will be undertaken by the Lower Willamette Group (LWG) as it develops and implements a remedial investigation and feasibility study (RI/FS) for the Portland Harbor Superfund Site (Site) in Portland, Oregon. The LWG is a group of Portland Harbor businesses and public agencies involved in the investigation and evaluation of ecological and human health risks at the Site. The Portland Harbor RI/FS Programmatic Work Plan (Work Plan) complies with the requirements of the Administrative Order on Consent (AOC) and Statement of Work (SOW) (EPA 2001a) between the LWG and the U.S. Environmental Protection Agency (EPA) for conducting the RI/FS.

As stated in the SOW, the purpose of the RI/FS is “to investigate the nature and extent of contamination for the in-water portion of the Site, to assess the potential risk to human health and the environment, to develop and evaluate potential remedial alternatives, and to recommend a preferred alternative” (EPA 2001a). A critical objective of the RI/FS will be to characterize the Site sufficiently to allow EPA to define site boundaries and select a remedy that is protective of the survival, growth, and reproduction of ecological receptors (e.g., benthic invertebrates, fish, shellfish, birds, and mammals, including those listed under the Endangered Species Act) and human receptors that may consume fish or shellfish or come in contact with sediments, surface water, or groundwater seeps from the Site.

The RI and FS will be conducted in an integrated fashion. Data needs for the RI and FS will be identified collectively, and results will be shared throughout the project such that the field investigation data, the outcome of the RI, and the associated risk assessments can support the development and evaluation of remedial alternatives. FS information that may affect the scope of the RI or risk assessments will also be incorporated into the RI approach. The RI/FS will initially focus on the stretch of the Willamette River from river mile (RM) 3.5 to RM 9.2 and adjacent areas logically associated with an evaluation of the in-water portion of this stretch of the river. This Work Plan refers to this initial study area as “the ISA.” The ISA does not define the Superfund Site; the boundaries of the Site will be determined upon issuance of a Record of Decision (ROD).

The RI/FS will be conducted in a manner that is consistent with the Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (EPA 1988), EPA’s Data Quality Objectives planning process (EPA 2000a), and other applicable guidance. This Work Plan describes the overall tasks to be conducted during the RI/FS, and provides the underlying rationale and objectives for each task, the data uses and analysis methods, and the principles that are being used to define the detailed sample collection and analysis efforts. Details of the sampling (e.g., locations, sampling methods) and the analytical methods are provided in the field sampling plans (FSPs) and the quality assurance project plans (QAPPs). Together, the FSP and QAPP comprise the sampling and analysis plan, which, in accordance with EPA guidance, are attachments to the overall Work Plan. EPA has approved the

Round 1 QAPP for use in the project. FSPs and the QAPP for the next round of sampling are being prepared and will be attached to this Work Plan. The overall organization of the RI/FS is described in Section 1.3. Details of the RI/FS program approach are summarized in Section 6, and the details of the RI/FS tasks are presented in Sections 7 and 8.

This Work Plan presents the RI/FS approach anticipated for the Site. Because additional data may be generated during the RI/FS that impacts the current understanding of the Site, the methods and assumptions presented in this Work Plan may be refined to incorporate new information. Changes to the RI/FS approach presented in this Work Plan will be discussed with EPA and its partners and submitted as interim deliverables or addenda prior to implementation. Similarly, it is anticipated that several technical memoranda will be prepared to provide detailed project approaches for various components of the RI, risk assessments, and FS. These memoranda will be submitted to EPA and its partners for review and approval, in accordance with the Work Plan schedule. Any EPA approved interim deliverable, addenda, or technical memorandum will be incorporated into this Work Plan and become a substantive part of this Work Plan under the AOC.

1.1 PORTLAND HARBOR OVERVIEW

Portland Harbor is located along an 11.6-mile dredged reach of the lower Willamette River (LWR) in Portland, Oregon (Figure 1-1 and Map 1-1) [1]. While the harbor area is heavily industrialized, it occurs within a region characterized by commercial, residential, recreational, and agricultural uses. Land use along the LWR in the harbor includes marine terminals, manufacturing, and other commercial operations as well as public facilities, parks, and open spaces. Map 1-2 illustrates land use zoning within the LWR, as well as waterfront land ownership.

Since the late 1800s, the Portland Harbor section of the LWR has been extensively modified to accommodate a vigorous shipping industry. Modifications include re-direction and channelization of the main river, draining seasonal and permanent wetlands in the lower floodplain, and relatively frequent dredging to maintain the navigation channel. Constructed structures, such as wharfs, piers, floating docks, and pilings, are especially common in the Portland Harbor where urbanization and industrialization are most prevalent. These structures are built largely to accommodate or support shipping traffic within the river and to stabilize the riverbanks for urban development. Riprap is the most common bank-stabilization measure. However, upland bulkheads and rubble piles are also used to stabilize the banks. Seawalls are used to control periodic flooding as most of the original wetlands

[1] In this Work Plan, the term “Portland Harbor” means the portion of the Willamette River containing the federal navigation channel, from RM 0 to RM 11.6. The terms “lower Willamette River” and “LWR” mean the portion of the Willamette River from Willamette Falls to its confluence with the Columbia River, or RM 0 to approximately RM 26.5.

bordering the Willamette in the Portland Harbor area have been filled. Constructed structures are clearly visible in the aerial photos provided in Maps 1-3a-n. Numerous municipal and private outfalls, including storm drains and combined sewer overflows, are located along both shores of the LWR in the metropolitan area.

A federal navigation channel, with an authorized depth of –40 feet, extends from the confluence of the LWR with the Columbia River to RM 11.6. Container and other commercial vessels regularly transit the river. Certain parts of the river require periodic maintenance dredging to keep the navigation channel at its authorized depth. In addition, the Port of Portland and other private entities periodically perform maintenance dredging to support access to dock and wharf facilities. Dredging activity has greatly altered the physical and ecological environment of the river in the harbor area.

While the ecological function of the LWR has been greatly modified by development, a number of species of invertebrates, fishes, birds, amphibians, and mammals, including some protected by the Endangered Species Act (ESA), use habitats that occur within and along the river. The river is also an important pathway for migration of anadromous fishes such as salmon and lamprey. Various recreational fisheries, including salmon, bass, sturgeon, crayfish, and others, use the LWR. A detailed description of ecological communities in the harbor is presented with the Ecological Risk Assessment Approach in Appendix B.

The long history of industrial and shipping activities in the Portland Harbor, as well as agricultural, industrial, and municipal activities upstream of the harbor, has contributed to chemical contamination of surface water and sediments in the LWR. Potential sources of chemical releases to the river are described in Section 3. As noted above, the primary purpose of this RI/FS is to characterize the effects of such chemicals on the environment in the LWR to the extent necessary to support risk management actions to protect human health and the environment.

1.2 NAVIGATIONAL CHANNEL AUTHORIZATION HISTORY

The LWR federal navigation project was first authorized in 1878 to deepen and maintain parts of the Columbia River and LWR with a 20-foot minimum depth. The channel for both rivers has been deepened at various intervals since that time. The navigation depth for both rivers was increased to 25 feet in 1899 and to 30 feet in 1912. Between 1930 and 1935, the navigation channel depth was again increased to 35 feet, and in 1962 the authorized depth was increased to 40 feet.

The current project authorization, as modified by Congress in 1962, encompasses 11.6 miles of the Willamette River below Portland and 103.5 miles of the Columbia River below Vancouver, Washington. Work on the authorized 40-foot-deep channel from Portland and Vancouver to the Pacific was completed in 1976. The Willamette

River channel, from the Broadway Bridge (RM 11.6) to the mouth (RM 0), varies in width from 600 to 1,900 feet.

1.3 SCOPE OF THE RI/FS

As stated in the SOW, the purpose of the RI/FS is "to investigate the nature and extent of contamination for the in-water portion of the Site, to assess the potential risk to human health and the environment, to develop and evaluate potential remedial alternatives, and to recommend a preferred alternative" (EPA 2001a). With respect to releases or threatened releases of any hazardous substances to the in-water portion of the Site, the RI/FS will specifically address the protection of human health, as well as survival, growth, and reproduction of the following ecological receptors:

- Benthic invertebrates
- Fish and shellfish
- Birds and mammals
- Species listed under the ESA.

In addition, the potential for risk to amphibians/reptiles will be evaluated.

Following completion of the RI/FS, EPA will prepare a ROD for the Site, which will define the site boundaries and potential cleanup areas and approaches. After the ROD is finalized, EPA will likely enter into a Consent Decree with one or more potentially responsible parties who will undertake remedial design (RD), remedial action (RA), and long-term monitoring of sediment management areas (SMAs) within the Site. Members of the LWG may or may not be signatories of the Consent Decree for the RD and RA.

The SOW identifies the ISA for the purpose of focusing sampling during implementation of the initial phase of the RI/FS. The ISA is defined as the lower Willamette River from RM 3.5 to 9.2, and adjacent areas logically associated with an evaluation of the in-water portion of this stretch of river (see Map 1-1). The actual boundaries of the Site will be determined through the RI/FS process and will be documented by EPA in one or more RODs when the final remedy is selected.

The SOW for the RI/FS (EPA 2001a) requires completion of a series of tasks:

Task 1 – Shared Server

Task 2 – Scoping

Task 3 – Community Relations

Task 4 – Dredging Coordination

Task 5 – Site Characterization

Task 6 – Treatability Studies

Task 7 – Development and Screening of Remedial Alternatives

Task 8 – Detailed Analysis of Remedial Alternatives.

This Work Plan completes the requirements of SOW Task 2 – Scoping, which is composed of the following subtasks:

Subtask 2a: Data Compilation/Site Background

Subtask 2b: Cultural Resources Analysis

Subtask 2c: Submission of Work Plans via the Stipulated Agreement

Subtask 2d: Data Review and RI Planning

- Preliminary Conceptual Site Model
- Preliminary Analytical Concentration Goals

Subtask 2e: Preliminary FS Planning Tasks

- Remedial Action Objectives Technical Memorandum
- Facility Siting Technical Memorandum
- Capping Material Evaluation

Subtask 2h: RI/FS Work Plan for the ISA.

The deliverables for subtasks 2a – 2e have been submitted under separate cover or are included in this Work Plan. The relationship of the RI to the remaining tasks is also summarized in Section 1.3.2. Subtask 2f (CERCLA/WRDA Integration and Coordination Plan) will be addressed outside the Work Plan process. The deliverable for subtask 2g (Early Actions Technical Memorandum) has been submitted to EPA as a part of earlier drafts of the Work Plan, and EPA has requested that it be removed from the Work Plan.

1.3.1 RI/FS Technical Approach

The RI/FS will be a multiyear program involving multiple rounds of data gathering and data evaluation as chemical distributions and the factors driving risks to ecological receptors and human health are identified. In concert with the RI field studies and data evaluations, data will be gathered to support the FS so that potential remedial alternatives can begin to be considered and evaluated as the RI/FS process identifies and refines potential areas for cleanup.

Pursuant to the SOW requirements, the RI/FS technical approach is based on EPA guidance documents. Included in this guidance is the recent EPA memorandum, Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites [Office of Solid Waste and Emergency Response (OSWER) Directive 9285.6-08 (EPA 2002b)], which identifies 11 key concepts to be considered in the RI/FS process for the Site:

1. Control Sources Early.
2. Involve the Community Early and Often.
3. Coordinate with States, Local Governments, Tribes, and Natural Resource Trustees.
4. Develop and Refine a Conceptual Site Model that Considers Sediment Stability.
5. Use an Iterative Approach in a Risk-Based Framework.
6. Carefully Evaluate the Assumptions and Uncertainties Associated with Site Characterization Data and Site Models.
7. Select Site-specific, Project-specific, and Sediment-specific Risk Management Approaches that will Achieve Risk-based Goals.
8. Ensure that Sediment Cleanup Levels are Clearly Tied to Risk Management Goals.
9. Maximize the Effectiveness of Institutional Controls and Recognize their Limitations.
10. Design Remedies to Minimize Short-term Risks while Achieving Long-term Protection.
11. Monitor During and After Sediment Remediation to Assess and Document Remedy Effectiveness.

Consideration of this and other guidance documents, frequent communication with the agencies, and experience at other sites were utilized in designing this Work Plan. The resulting risk-based technical approach relies upon the initial use of existing data, the data quality objectives (DQO) process, iterative evaluation of data to guide subsequent activities, and identification of ongoing sources to focus the timely and efficient completion of the RI/FS. It is important to note that Oregon Department of Environmental Quality (DEQ) has the primary responsibility for identifying and directing control of upland sources to the Portland Harbor Superfund Site.

A flowchart depicting the generalized RI/FS process is shown in Figure 1-2. The technical approach is summarized in the following section and is described in detail in Section 6.

1.3.2 Overview of RI/FS Tasks

As shown in Figure 1-2, the RI/FS Work Plan builds upon information and evaluations developed as part of the Task 2 scoping effort, and lays out the "road map" for completion of the RI, baseline risk assessments, and FS. The steps in the RI/FS process shown in Figure 1-2 are coded with a number referenced in the following text (the text also provides the applicable SOW task/subtask number). Each step is discussed in detail in subsequent sections of the RI/FS Work Plan. These steps are briefly described below as an introduction to the overall process:

1. **Compilation and Evaluation of Historical Data (Box 1 in Figure 1-2, SOW Subtask 2a).** The RI/FS was initiated with an extensive compilation of existing information, which is summarized within this Work Plan (primarily Sections 2, 3, and 4) and associated appendices (particularly Appendices B, C, D, E, and F). Nearly 700 documents and data sets were obtained that address conditions in the LWR. This information was used to develop an initial understanding of the physical, chemical, and biological processes at the site and to assist in the development of the conceptual site model for the ISA (Section 5) and identification of data gaps (Section 7). At EPA's request, revisions to the preliminary conceptual site model presented in this Work Plan will be updated and resubmitted as a stand-alone report prior to development of the Round 2B sediment coring field sampling plan.

2. **Phase 1 Studies (Box 2, SOW Subtask 2c).** Recognizing that critical new site-specific physical and biological information was necessary to begin scoping the Work Plan, the LWG performed the following four pre-AOC "Phase 1" field studies approved by EPA in a stipulated agreement (EPA 2001b):

    - Juvenile salmonid residence time field study (Ellis Ecological Services 2002)
    - Multibeam acoustic bathymetry survey from RM 0 to Ross Island (DEA 2002a)
    - Integration of a sediment trend analysis and an evaluation of historical bathymetry (SEA 2002b)
    - Sediment-profile imaging field study (SEA 2002f).

Reports documenting the results of these pre-AOC “Phase 1” studies have been provided to EPA.

3. **RI Scoping Process (Box 3, SOW Subtask 2d and 2h).** During Work Plan development, the LWG and EPA undertook an extensive scoping process to allow a more focused approach to the RI/FS and associated risk assessments. In addition to developing and maintaining a high level of communication with the EPA Remedial Project Manager and staff, communication between the LWG, DEQ, Natural Resource Trustee agencies, and Tribes was a key element of the initial scoping. The LWG directed its consultant team to meet with EPA’s technical support staff to identify issues that will need to be addressed in the RI and risk assessments and to discuss various approaches for addressing those issues.

   Historical data that were available to the LWG were compiled and reviewed for quality and utility in supporting the RI/FS and risk assessments. As part of the data review, DQOs for determining the usefulness of a given historical data set were developed and documented in a technical memorandum to EPA (SEA 2001b). Historical chemical data were compiled for use by all the parties in a relational database for easy retrieval, summarization, or transfer to geographic information systems and other software. Existing data are summarized in Section 4, and additional information is found in the Work Plan appendices described in more detail below.

   A preliminary conceptual site model (CSM) was developed based on the current understanding of the physical and biological characteristics of the ISA. Data gaps that need to be filled during the RI/FS also were identified, including data needed for developing and evaluating remedial alternatives. The preliminary conceptual site model is found in Section 5 of this Work Plan.

   A CSM will be developed that portrays the relationship among sources, chemicals, transport mechanisms (including sediment transport, surface runoff and groundwater discharges to the Site), receptors, and other parameters that are determined to be relevant.

   A CSM will be submitted in accordance with the approved schedule. The purpose of the CSM is to:

   1. Focus sampling.
   2. Gain a better understanding of potential contaminant loadings from upland sources (including direct discharge, overland transport, groundwater and bank erosion) and the relative importance of the various transport mechanisms in different river miles.

3. Identify where there may be continuing sources of contamination and pathways to the river (including persistent bioaccumulative toxins) based on historical site use information, site information and analytical data.
4. Identify historical sources of contamination and pathways to the river.
5. Identify overwater activities that may have released contamination to the Willamette River sediments.
6. Identify areas of the river where recontamination of sediments by upland and other sources is a risk.
7. Gain insight regarding upland source control strategies and help DEQ identify where additional work must be done by responsible parties and DEQ on upland sites.

Updated versions of the CSM will be submitted in the future as additional data are evaluated and the CSM is refined. Data needed to complete the RI/FS are identified in Sections 7 and 8.

Preliminary analytical concentration goals were developed from risk-based screening levels and method reporting limits, and were used to assist in the development of the Round 1 Quality Assurance Project Plan (SEA 2002e) that was approved by EPA (2002a). A technical memorandum providing this information was initially submitted to EPA on January 25, 2002 (SEA 2002c); the memorandum was revised based on EPA comments and resubmitted on April 1, 2002 (Windward et al. 2002).

The Work Plan and companion documents (SOW Subtask 2g) compile the results of the RI/FS scoping process. Field sampling plans (i.e., sampling and analysis plans referenced in Section 4.9.1 of the SOW), and site health and safety plans have been submitted under separate cover.

4. **FS Planning (Box 4, SOW Subtask 2e).** Prior to completion of this Work Plan, tasks to specifically assist in the planning of the FS were undertaken, including the development of preliminary remedial action objectives, methods for ensuring that capping material will meet remedial action objectives, and a process for siting a contaminated sediment disposal facility. These tasks are described in Appendix A.

5. **Early Action Evaluation (Box 5, SOW Subtask 2g).** A draft technical memorandum on Early Actions was submitted to EPA in two earlier drafts of this Work Plan. EPA has directed that this memorandum be removed from the Work Plan, and it is not discussed further in this document.

Implementation of any Early Actions will occur by separate agreement with EPA rather than as part of the AOC for the RI/FS.

6. **Remedial Investigation – Site Characterization (Box 6, SOW Task 5).** The RI will be implemented as an iterative process involving evaluation of risk, use of DQOs to identify data needs, field studies, and data evaluation. The steps taken to assess RI data needs are presented in Section 7. Results of this data evaluation process form the basis of the Round 2 field sampling plans, submitted under separate cover. Currently, four rounds of sampling (i.e., pre-AOC sampling/data and Rounds 1, 2, and 3), as described in Section 6, are anticipated, although the need for additional sampling rounds may be identified later. Consistent with EPA guidance, the goal of the RI is not to eliminate uncertainty, but to reduce it enough to allow sound risk management and remediation decisions.

   For each round of field sampling plans, the DQO process will be used to identify specific decisions and the quality and quantity of data needed to make the decisions. Field sampling plan addenda may also be prepared that describe data collection needed to address the data needs during the same field season. Resulting data will then be analyzed to determine if risk is sufficiently well understood to allow decisions regarding risk management and remedial actions.

7. **Baseline Risk Assessments (Box 7, SOW Task 5).** Draft baseline human health and ecological risk assessments will be prepared following the Round 3 data collection effort. The baseline risk assessments will be based on pre-AOC, Round 1, Round 2, Round 3, and historic Category 1 data, as well as other data agreed to by EPA and the LWG. Following Round 1, an ecological preliminary risk evaluation report will be prepared to help frame data gaps and information needs to complete the baseline ecological risk assessment. The approaches to the ecological and human health risk assessments based on the anticipated RI/FS process are summarized in Section 7 and provided in detail in Appendices B and C, respectively. If needed, modifications to the risk assessment methodologies and procedures presented in this Work Plan will be discussed with EPA and its partners and submitted as technical memoranda.

8. **Feasibility Study (Box 8, SOW Tasks 6, 7, and 8).** The FS will be conducted from the beginning of the overall RI/FS process, as much of the data collected throughout the process (e.g., subsurface coring samples, water samples, sediment physical characteristics, and bathymetry) will be of significant value to the FS. In addition, some preliminary documents have been generated that are primarily concerned with FS-related tasks, including:

- Preliminary Remedial Action Objectives Technical Memorandum
- Disposal Facility Siting Evaluation Technical Memorandum
- Capping Material Evaluation Technical Memorandum
- Natural Attenuation Data Gaps Technical Memorandum.

These memos are provided in the detailed FS approach contained in Appendix A of this Work Plan. The last bullet, Natural Attenuation Data Gaps Technical Memorandum, identifies information needs for evaluating natural attenuation. This issue is addressed several times throughout this document because the Work Plan provides the basis for determining data needs and approaches to collecting those data.

Based on the methods described in the above memos and the requirements of the SOW, the following FS tasks will be conducted during the course of the RI:

- Facility siting evaluation
- Natural attenuation sampling and modeling (in several steps)
- Treatability study literature survey and needs determination
- Refinement of areas and volumes of sediment requiring remediation.

Development of this information in concert with the RI will allow the FS to proceed without delay once the RI and risk assessments have been completed. As the RI is proceeding, the volume and extent of sediments that appear to require remediation will be defined for the FS. As more definitive information is generated by the risk process, these sediment volumes and extents can be further refined and the process of developing remedial areas (i.e., SMAs) and developing remediation alternatives can begin. The development of the remediation alternatives will mark the formal beginning of the FS process and will likely start as the RI and baseline risk assessments are being completed. Areas of localized risk and site-wide risk will be considered in the FS.

There will continue to be considerable interaction between the risk assessors and the FS team during the determination of SMAs and during the evaluation of potential remedial alternatives as the risk team evaluates the risk reductions associated with the various remedial alternatives. Once a set of potential remedial alternatives has been developed for each SMA, the FS will follow CERCLA guidance and evaluate the set of remedial alternatives against the nine CERCLA evaluation criteria. These criteria are summarized in Section 8 and detailed in Appendix A.

1.3.3 RI/FS Data Generation and Reporting

Major components of the RI/FS process will include identifying data needs, developing work plans and possible related addenda to fill data gaps, and generating and evaluating the resulting data. Currently, it is anticipated that these steps will be repeated four times (including the pre-AOC studies conducted in 2001) before the RI and FS are completed. Additional focused data gathering in support of remedial design and remedial action may occur after the ROD. The RI process is both iterative and sequential. Validated results with corresponding sampling location information from previous rounds of investigation will be documented and provided in accordance with the approved project schedule to EPA for review to guide in scoping subsequent rounds of the investigation. The Round 1 data, collected in 2002 and described in greater detail below, will be evaluated in a Round 1 site characterization summary report and an ecological preliminary risk evaluation report (described below), both of which will be submitted within 120 days after the Round 1 data collection and analysis effort is completed. It is anticipated that several Round 2 FSPs will be developed to address the various investigation tasks defined for Round 2 (Section 7).

Validated analytical data will be provided to EPA within 90 days of each sampling activity (e.g., Round 2 surface sediment sampling, Round 2A sediment coring, Round 2B sediment coring, sediment beach sampling, surface water sampling, groundwater pathways sampling, Round 3 sampling and any other sampling activity). As specified in the AOC, and upon request, analytical data will be made available to EPA within 60 days of each sampling activity. Field sampling reports will be prepared and submitted to EPA within 60 days of completing of each sampling activity. The field sampling reports will summarize field sampling activities, including sampling locations (maps), requested sample analyses, sample collection methods, and any deviations from the FSP. Sample analysis results will be reported in tabular format in site characterization reports within 120 days of completing sampling and analysis for each sampling activity. Data will be provided in electronic format showing location medium and results. Data will be provided in sufficient detail for EPA and its partners to begin preliminary analysis.

Round 2 data evaluation results will be presented in the comprehensive site characterization summary and data gaps analysis report (together with pre-AOC and Round 1 data), which is planned for submittal 120 days after the Round 2 data collection and analysis effort is completed. The ecological and human heath baseline risk assessment reports will be submitted concurrently with the RI report, which will be prepared after all sampling and analysis rounds for the project are completed.

The EPA (2000a) DQO process was applied to the existing data (see Section 7). Results of this data evaluation process form the basis of the field sampling plans, submitted under separate cover. A similar data evaluation and DQO process will occur following the evaluation of data generated during Rounds 1 and 2. The DQOs will be updated and focused following the various Round 2 investigation efforts to incorporate new data. Prior to future sampling events, work plan addenda will be prepared, in which the DQO process will be revisited and the new data needs identified. Field sampling plans will be prepared to address the new sampling needs.

Round 1 sampling was conducted in the summer and fall of 2002, prior to the approval of the Work Plan. Sampling in 2002 was conducted in accordance with the Round 1A and Round 1 field sampling plans (SEA et al. 2002b,c). Round 1A sampling (described in the Round 1A FSP) included:

1. Collection of fish and shellfish tissue for chemical analysis
2. Evaluation of epibenthic colonization using multiplates
3. Reconnaissance survey of plants and amphibians
4. Reconnaissance survey of adult lamprey
5. Measurement of riverbank erosion and accretion using sediment stakes
6. Multibeam bathymetry – low water.

The subset of Round 1 sample collection tasks (described in the Round 1 FSP) that were approved by EPA in September 2002 included:

1. Beach sediment chemistry
2. Reconnaissance-level benthic infauna community analysis
3. Collocated sediment chemistry at sculpin, crayfish and benthic infauna stations.

In September 2002, the LWG also undertook a reconnaissance survey of juvenile lamprey and benthic infauna for potential tissue analysis. Because these were the only data collection efforts in 2002, the combined efforts are referred to simply as "Round 1" sampling in the remainder of this document.

Results of each of these sampling tasks will be submitted to EPA either as stand-alone data reports or as part of the Round 1 Site Characterization Summary Report. A list of all RI/FS project reports and deliverables provided to EPA through September 2003 is presented in Table 1-1.

Round 2 will focus on determining the distribution of chemicals in sediments in the ISA. Also, water quality data will be collected to evaluate potential effects of sources on the river system and to support the risk assessments. These data will be used, along with Round 1 and historic Category 1 results, to identify areas with elevated concentrations of chemicals in the sediments and the water column, and tissue residue levels, so that risk estimates can be made to identify the receptors and pathways that appear to be driving risks at the Site. The derivation of the Round 2 sampling program, and the associated data uses, are described in detail in Section 7 of this Work Plan.

Round 3 work will be conducted to refine sediment management areas (including principal threats areas, if necessary), gather data for the evaluation of FS alternatives, and fill in risk assessment or RI data gaps, as necessary.

1.4 CULTURAL RESOURCES

The LWG has initiated planning activities for an evaluation of cultural resources and cultural uses using a typical approach provided for under Section 106 of the National Historic Preservation Act (16 USC Section 470). The LWG will coordinate cultural resource work with appropriate tribes to ensure a full and comprehensive cultural resource analysis is done when characterizing Site use. The cultural resource analysis will be initiated in 2004 following receipt of a memorandum from EPA that defines the scope of work and will be considered in future work.

1.5 COMMUNITY RELATIONS

As described in the SOW (Section 5, Task 3), the development and implementation of the plan are the responsibility of EPA.

1.6 WORK PLAN ORGANIZATION

This Work Plan, consisting of 11 sections and seven associated appendices, contains information for the overall implementation of the RI/FS. As approved by EPA in a letter dated April 10, 2002, background information on the Site is provided within the Work Plan and associated appendices instead of in a separate historical data compilation report. Consequently, the body of the Work Plan contains considerable detail on Site background information. Several appendices are also significant documents that include additional data summary information, as well as the ecological risk assessment (ERA) approach, the human health risk assessment (HHRA) approach, and the FS approach. A preliminary CSM is presented in Section 5. Revisions to the CSM will be submitted prior to the development of the Round 2B sediment coring FSP. The Round 1 QAPP (SEA 2002e) for the Site has already been submitted to, and approved by, EPA. A Round 2 QAPP will be prepared, and approved by EPA, before Round 2 sampling activities are conducted. The Health and Safety Plan (SEA 2002d) has also been provided to EPA. Field sampling plans will contain the rationale for sampling, as well as the sampling station locations, numbers of samples, and analytes. They will also contain sampling and analysis methods. The remaining sections of this Work Plan include the following information:

Section 2: Physical Setting. This section discusses the physical attributes of the study area, including hydrogeology, hydrology, bathymetry, and physical characteristics of sediments, sediment transport, and dredging.

Section 3: Chemical Sources. This section describes different types of chemical sources that may affect the ISA, and chemical transport.

Section 4: Summary of Previous Investigations. This section contains an overview of previous sediment, water quality, ecological, and cultural and human use studies. The data quality review process that was applied to the existing chemical and biological data is also discussed in this section. Additional information on ecological receptors is provided in Appendix B (Ecological Risk Assessment Approach).

Section 5: Preliminary Conceptual Site Model. This section presents the physical, ecological, and human health conceptual site models.

Section 6: Overview of Portland Harbor Site RI/FS Process. This section contains the road map for the project, including sections on remedial action objectives, sampling rounds, ecological and human health risk assessment, reporting, feasibility study, and the Record of Decision.

Section 7: Site Characterization Approach. This section contains the DQOs developed for each significant work element, a description of the data needed for those work elements, a description of the RI and risk assessment task work elements, and information on how those data will be used in the RI/FS.

Section 8: Feasibility Study Approach. This section contains the DQOs developed for each significant FS work element, a description of the data needed for those work elements, a description of the FS task work elements, and information on how those data will be used in the FS.

Section 9: Project Management Plan. This section reviews information on how the project will be managed, including roles and responsibilities, contact information, communications, schedules, and cost control.

Section 10: References. This section contains references for the documents cited in the Work Plan.

Section 11: Glossary of Terms. This section contains definitions of terms used in the Work Plan.

As noted above, the following appendices to this Work Plan are, in themselves, significant documents:

Appendix A: Feasibility Study Work Plan. This appendix contains the approach for conducting the FS, as well as the four FS-related technical memoranda required by the AOC. This approach is summarized in Section 8 of this Work Plan.

Appendix B: Ecological Risk Assessment Approach. The ecological risk assessment approach is discussed in detail in Appendix B. A brief overview of the ERA approach is provided in Section 7.3 of this Work Plan.

Appendix C: Human Health Risk Assessment Approach. Similar to Appendix B, Appendix C contains the detailed human health risk assessment approach. A brief overview of the approach is also provided in Section 7.4.

Appendix D: Changes in Sediment Volume. Appendix D contains a series of graphs, organized by river mile, that show net change in sediment volume in Portland Harbor since 1990. These graphs were developed by comparing sequential bathymetric surveys performed in the federal navigation channel by the U.S. Army Corps of Engineers (Corps), Portland District. A description of the process used to generate the graphs is included.

Appendix E: Chemical Sources and Spill Records. This appendix contains information on chemical sources and Oregon Department of Environmental Quality (DEQ) spill records.

Appendix F: Data Sources and QA/QC Reviews. The sources of information compiled to develop the Work Plan are provided in Appendix F. For ease of use, Appendix F is organized by subject. Assessments of data quality assurance/quality control (QA/QC) are also provided for sediment chemistry, water chemistry, tissue chemistry, bioassays, and benthic infauna surveys.

Appendix G: Data Management Plan. This final appendix contains the project Data Management Plan.

2.0 PHYSICAL SETTING

This section describes the physical setting of the Portland Harbor Site, including an understanding of the hydrogeology in the vicinity of the ISA, as well as river hydrology, bathymetry, physical sediment characteristics, fate and transport processes, and dredging history. Each of these factors must be considered in the development of the conceptual site model, future sampling events, and the design of remedial alternatives. This discussion focuses primarily on the physical setting in the ISA and immediately adjacent areas of the Portland Harbor. However, LWR and Willamette basin physical features are also described generally as warranted based on their potential influence on the Site. A corresponding presentation of the ecological setting of the ISA is provided as part of Appendix B (Ecological Risk Assessment Approach).

The Willamette River drains the Willamette basin from the Cascade Range to the Coast Range. The river basin has a drainage area of 11,500 square miles and is bordered by foothills and mountains of the Cascade and Coast ranges up to 10,000 feet high to the south, east, and west (Trimble 1963). The main channel of the Willamette forms in the southern portion of the valley near Eugene, at the convergence of the Middle and Coast forks. It flows through the broad and fertile Willamette Valley region and at Oregon City flows over the Willamette Falls and passes through Portland before joining the Columbia River.

The Willamette flows predominantly from the south to the north and has a total channel length of about 309 miles. It is the 10th largest river in the contiguous United States in terms of volume and the 13th largest in terms of discharge. The portion of the river from the Willamette Falls to the Columbia is considered the lower Willamette River (Map 1-1).

Water velocity in the Willamette is variable, but is generally higher in the upstream reaches of the river. Major tributaries draining the Coast Range and flowing east into the main channel of the Willamette include the Mary's, Luckiamute, Yamhill, and Tualatin rivers. The McKenzie, Calapooia, Santiam, Mollala, and Clackamas rivers flow westward from the Cascades into the Willamette. The Pudding River flows south to north and intersects the Mollala before flowing into the Willamette south of Portland.

The upstream reaches of the Willamette constitute a meandering and, in some cases, braided river channel. Upstream flooding is largely controlled by 13 major tributary reservoirs (Uhrich and Wentz 1999). In the LWR, especially near and around Portland, the channel banks have been stabilized, and the channel itself has been deepened to an authorized depth of –40 feet. These measures have created a stable channel in the LWR. The federally maintained navigation channel defines Portland Harbor and extends upstream from the Columbia River to RM 11.6 (Broadway Bridge) (Map 1-1). From 1973 through 2000, annual mean flow in the Willamette

River flow averaged approximately 33,800 cubic feet per second (cfs) at the Morrison Bridge in Portland.[2]

2.1 HYDROGEOLOGY

The generalized hydrogeology of the ISA is presented in this section. This information represents the current understanding of the general hydrogeologic setting of the ISA. Additional information will be developed during the RI/FS to further the understanding of the hydrogeology of the ISA. The detailed hydrogeology of the upland areas on both sides of the river varies by location. This generalized discussion is intended to describe the important basic hydrogeologic units and their properties and groundwater flow within the ISA and does not completely represent any one particular location. An upland groundwater data review that summarizes information from a review of hydrogeologic and groundwater quality data from upland sites in the vicinity of the ISA has been completed by the LWG. Results of groundwater reviews will be provided in Conceptual Site Model updates.

2.1.1 Geologic Setting

The ISA is located along the southwestern edge of a large geologic structure known as the Portland Basin. The Portland Basin is a bowl-like structure bounded by folded and faulted uplands. These northwest-trending structural zones are interpreted as dextral wrench faults that delineate the Portland, pull-apart basin (Beeson et al. 1985; Yelen and Patton 1991).

The basin has been filled with up to 1,400 feet of alluvial and glacio-fluvial flood deposits between the middle Miocene [approximately 12 million years ago (mya)] and the present. These sediments overlie older (Eocene and Miocene) rocks including the Columbia River Basalt Group (CRBG), Waverly Heights basalt, and older marine sediments. The older rocks are exposed where uplifting has occurred on the margins of the basin, including adjacent to the ISA.

Because the ISA is located at the edge of the basin, both the older rocks and overlying sediments are present near the surface and play a significant role in defining interactions between groundwater and the river. The geologic units found in the area of the ISA are illustrated in Figure 2-1 and briefly described below from youngest to oldest (Beeson et al. 1991; Swanson et al. 1993):

- **Recent Fill.** Fill blankets much of the lowland area next to the river and is predominantly dredged river sediment, including fine sand and silty sand. Hydraulic dredge fill was used to fill portions of the flood plain, such as Doane Lake, Guilds Lake, Kittridge Lake and Mocks Bottom, and a number of sloughs and low-lying

[2] Data obtained from the U.S. Geological Survey Water Resources web site (http://waterdata.usgs.gov/or/nwis/sw).

areas. The fill also was used to connect Swan Island to the east shore of the Willamette River and to elevate or extend the bank along significant lengths of both sides of the riverfront by filling behind silt and clay artificial and natural flood levee dike structures. Rocks, gravel, sand, and silt also were used to fill low-lying upland and bank areas. The thickness of this unit ranges from 0 to 20 or more feet. The permeability of this unit, where composed of clean dredge fill sand, is higher than the natural fine-grained alluvium. The presence of silt fill or a silty matrix in the sand fill generally reduces the permeability of the unit significantly.

- **Fine-grained Pleistocene Flood Deposits and Recent Alluvium (Undifferentiated).** This unit includes fine-grained facies of the Pleistocene Flood Deposits, as well as recent alluvium deposited by the present Willamette River. This unit generally consists of silt, clay, silty sand, and fine to medium sand that borders and underlies the present floodplain of the river (Beeson et al. 1991). The lower portions of this unit and where it forms the large bluffs bordering the east side of the river likely consist of the fine-grained facies of the flood deposits; whereas the upper portions near the river are likely more recent alluvium. The upper fine-grained portion of the unit has likely been reworked and deposited by the present Willamette River. The sands of this unit may be indistinguishable from overlying dredge fill in some places (Landau Associates 2002). The thickness of this unit ranges from 20 to over 100 feet. The permeability of the clay, silt, and silty sand of this unit is generally relatively low, whereas the portions of the unit consisting of clean sands may have a relatively higher permeability. This unit forms part of the Unconsolidated Sedimentary Aquifer regional hydrostratigraphic unit proposed by Swanson et al. (1993).

- **Coarse-grained Pleistocene Flood Deposits (Gravels).** This unit includes fluvial deposits from the Pleistocene Missoula floods. The deposits fill deep channels that were incised into the Troutdale Formation and CRBG during the floods. The unit consists of uncemented sand, gravel, and cobbles with boulders in places. This unit is generally between 10 and 200 feet thick in the vicinity of the ISA and underlies fine-grained flood deposits and recent alluvium under much of the ISA. The Willamette River subsequently incised the flood deposits in places. The rise in sea levels from the end of the Pleistocene to the present created aggradational conditions that resulted in the filling of the incised channel by finer-grained flood and recent alluvial facies to form the current floodplain channel of the river. .

- **Upper Troutdale Formation.** The upper Troutdale Formation in the vicinity of the LWR includes cemented and uncemented alluvial sand, gravel, and cobbles deposited by the ancestral Willamette and Columbia rivers. The Troutdale Formation comprises the Troutdale Gravel Aquifer hydrostratigraphic unit. This unit is present in some places on the west side of the ISA to thicknesses of 100 feet, and is present along the entire length of the east side of the ISA at thicknesses of up to 200 feet (Swanson et al. 1993).
- **Lower Troutdale Formation/Sandy River Mudstone.** The Sandy River Mudstone (SRM) is a fine-grained equivalent (over-bank facies) of the lower Troutdale Formation (channel facies) that overlies the CRBG in the center of the basin and at the margins of the basin away from the axis of the Columbia River. The SRM is present in places under the LWR (Swanson et al. 1993) and borders the Portland Hills, but is not considered a significant hydrogeologic unit within the ISA. The SRM consists mostly of silt and clay with lenses of sand and gravel. The SRM tends toward fine-grained (low permeability) textures at the basin margins (Swanson et al. 1993).
- **Columbia River Basalt Group.** The CRBG consists of a thick sequence of Miocene basalt flows dating from between 17 mya and 6 mya, but the CRBG flows that underlie much of the Portland Basin entered the area between 16.5 mya and 12 mya. Basalt flows of the CRBG were folded and faulted during the uplift of the Tualatin Mountains, concurrent with eruption and emplacement of younger flows present in the Portland Basin (Beeson et al. 1991). The CRBG is present at the surface or at relatively shallow depths along the west side of the ISA and may be in direct contact with the river in places. The top of the unit drops off below ground surface (bgs) over a relatively short distance and is 400 or more feet bgs on the east side of the ISA. The thickness of the CRBG in the vicinity of the ISA is estimated to be approximately 600 feet (Beeson et al. 1991).

2.1.2 Hydrogeologic Units

The geologic units described above can be grouped into ISA-wide hydrogeologic units on the basis of having generally similar hydrogeologic characteristics. Important hydrogeologic characteristics include the position of the groundwater surface relative to each hydrogeologic unit, the physical relationship between each hydrogeologic unit and the river, and physical characteristics of each hydrogeologic unit, such as permeability, heterogeneity, and anisotropy.

These hydrogeological units are described from uppermost to lowermost in the following sections:

Fill, Fine-grained Facies of Flood Deposits, and Recent Alluvium (FFA). The FFA unit is composed of the fill, and the combined fine-grained facies of the Pleistocene flood deposits and Recent alluvium geologic units described by Beeson et al. (1991), and in Section 2.1.1. This unit encompasses a broad range of soil textures and hydraulic characteristics that blankets much of the lowland area next to the river and comprises much of the material abutting the river. The unit consists of the fine sand and silty sand dredge fill overlying recent and Pleistocene silt and clay overbank sediments, which are interbedded with lenses and layers of fine to coarse sand. As discussed in Section 2.1.1, the dredge fill was placed behind low-permeability, artificial and natural flood levee dike structures in some locations. The overall thickness of this unit ranges up to 150 feet; the thickness of the unit more typically ranges between 30 and 100 feet.

The FFA hydrogeologic unit is the primary unit of importance in defining the interactions between upland groundwater and the river because of the following characteristics of the unit:

- The unit forms most of the river channel within the ISA as well as the surrounding upland areas, and therefore controls groundwater interactions with the river.
- Most groundwater chemical plumes present in the upland areas occur within strata of this unit.

The distribution of textures and thus groundwater flow properties of the unit vary both vertically and horizontally by location along the ISA. Silt, clay and silty sand are present adjacent to the river at a majority of locations where the unit is observed near low river stage levels. Boring logs at sites north of RM 4 on the east side of the river indicate that a greater portion of the unit north of RM 4 and at depths below low river stage levels consists of sand layers. Comparison of hydraulic conductivity values for different textures within the FFA unit listed below illustrates the importance of the channel sand lenses and layers in focusing groundwater fluxes to the river at any particular location where present within this unit:

- Silt/clay: 0.005 to 2 feet per day
- Silty Sand: 0.1 to 2 feet per day
- Sand: 0.5 to 30 feet per day.

Typical measured hydraulic conductivities in the silt/clay facies of the FFA indicate that groundwater fluxes from these sediments within the ISA are generally low. Observations of seeps present in silt/clay during the seep reconnaissance survey (GSI 2003b) are consistent with this conclusion. Conversely, groundwater fluxes from the uplands to the river within the FFA are expected to be greater in those areas where more permeable sand zones are present.

Coarse-grained Flood Deposits and Upper Troutdale Formation (CGF). The CGF unit combines the unconsolidated coarse-facies flood deposits, including sands, gravels and cobbles, with the underlying uncemented and cemented gravels and cobbles of the upper Troutdale Formation. The flood gravels comprising the upper portion of this unit typically occupy scour channel surfaces on older units (e.g., the CRBG). Fill, silt, clay, and sand of the flood deposits and alluvium mostly blanket the CGF, except in places on the highland bluffs on the east side of the river where the unit may be exposed.

The CGF unit is adjacent to and underlies much of the ISA to thicknesses exceeding 200 feet. The overall thickness of the unit is more typically in the range of 100 feet. However, the unit is missing in places, including on the west side of the river towards the south end of the ISA and directly under the river at RM 7. The top of the CGF unit is present at elevations of 0 feet to over -100 feet mean sea level (MSL). The unit is present at relatively shallow depths adjacent to the west side of the river in the vicinity of the Doane Lake area, and may be in contact with river sediments (Figure 2-1). The hydraulic conductivity of this unit measured in the vicinity of the Doane Lake area ranges from 3 feet per day to greater than 40 feet per day (AMEC 2001).

This unit may act as a preferential groundwater flow pathway for groundwater flow to deeper units and for deeper groundwater flow to the river where the unit is present adjacent to the river. Higher fluxes to the river within the CGF unit may increase downward gradients and thus groundwater and contaminant plume movement in the FFA unit. The effect of the CGF unit on groundwater flow in the FFA is a factor in the selection of characterization methods. Locations where the CGF unit may exert a stronger influence on deeper groundwater flow to the river and thus vertical gradients in the FFA include the Doane Lake area, the southern edge of the ISA, and on the east side of the river in the vicinity of the International Terminal.

Lower Troutdale Formation/Sandy River Mudstone. This hydrogeologic unit is present in some places under the west side of the ISA and is present under the entire length of the east side of the ISA. The unit is predominantly silt and clay where explored in the vicinity of the ISA, and thus the permeability of the unit is low. Where present, the unit overlies the CRBG below depths of –100 to –150 feet MSL, and tends to pinch out on the west side and towards the southern end of the ISA where the CRBG is present at shallower depths. The unit typically is separated from the river by at least 100 to 200 feet of alluvium and the upper Troutdale Formation. Based on the hydrogeologic characteristics of this unit and the depth relative to the river, it is not considered to contribute significantly to surface water/groundwater interactions within the ISA.

Columbia River Basalt Group. The CRBG consists of a concordant sequence of basalt lava flows. Groundwater flow in the CRBG is focused along the higher permeability interflow zones and in some areas of fracture-enhanced permeability (e.g., faults). Hydraulic conductivities measured in individual basalt interflow zones in the vicinity of the ISA range from 1.5 to 10.9 feet per day (AMEC 2001). Hydraulic conductivities measured in CRBG basalt flow interiors at Hanford, Washington, range from 1 x 10^{-4} to 1 x 10^{-7} feet per day (Strait and Mercer 1986), illustrating that the basalt interflow zones (flow top and bottom collectively) are the primary groundwater flow pathways in the CRBG.

The CRBG is present at relatively shallow depths along portions of the west side of the ISA and may be in direct contact with the river in places. The top of the unit is irregular on the west side of the ISA with channels from scouring by flood events and the ancestral Willamette River. The top of the unit on the west side of the ISA is between elevation 0 MSL and – 50 feet MSL north of RM 9, except for an ancestral channel in the vicinity of Doane Lake. The top of the CRBG slopes down to an elevation of –250 feet MSL or more across the river on the east side of the ISA (Figure 2-1). The relief of the unit across the ISA appears to be due to structural downwarping towards the center of the basin, and may be accentuated by normal faulting postulated along both sides of the ISA (Beeson et al. 1991; Beeson 2003). The overall significance of the CRBG with regard to groundwater/surface water interactions within the ISA is not known; however, the CRBG is considered for to be most relevant to groundwater interactions with the river on the west side of the river downstream of about RM 9 because of its proximity to the river.

2.1.3 Groundwater Flow

Up to three general groundwater flow systems of interest are recognized along the ISA: a shallow (shallow FFA), an intermediate (deep FFA), and a deep (CGF and CRBG) system. A deeper, regional flow system also is present, which includes the CRBG where it is deep below the river (on the east side of the river) and lower Troutdale Formation/SRM. This deeper, regional flow system is not considered to be important in understanding the critical interactions directly between upland groundwater and the river that are relevant to this RI/FS.

At a local level, these divisions between flow systems are likely indistinct in places along the ISA. Many investigations have focused on the FFA and, in places, the CRBG, and have identified further flow system refinements or divisions based on the local hydrogeology. However, the general flow systems described above appear to apply for the majority of the ISA and provide a basis for evaluating variations from the general model.

The Willamette River is the focus of discharge for the three flow systems of interest to the RI/FS, including where the CRBG is present near the surface on the west side of the river. The shallow flow system is the primary focus of most upland groundwater investigations, and will be the focus of this RI/FS because most of the upland groundwater affected by contaminants of interest is present within this system, and this system discharges to the shallow and nearshore areas where exposure to human and ecological receptors is most likely. The potential for impact to the deeper system is relatively low, except where there may be a large source of dense non-aqueous phase liquid (DNAPL) that has the potential to migrate to the FFA and/or upper portion of the basalt. Impact to sediments from the shallow and intermediate flow systems will be the focus of the Work Plan effort (described in Section 7), except at locations where the CGF and CRBG appear to be impacted by chemical constituents and are connected to the river.

Shallow Flow System

A shallow, unconfined, groundwater flow system along the margins of the ISA consists mostly of fill and alluvial silt and clay deposits and some medium to coarse-grained channel sand of the shallow FFA that blankets the lowlands next to the river (Figure 2-1). At many locations, the shallow flow system is hosted within the lower portion of fine dredge fill sand and underlying silty sand and silt. The shallow system is recharged by direct precipitation and infiltration, infiltration from the hills on the west side of the ISA, and exchange with several surface water bodies along the ISA (e.g., Doane Lake). Groundwater in this system is unconfined. Groundwater level data in the upland areas indicate that there is a downward gradient toward deeper units from the shallow system. Groundwater levels and fluxes in the shallow system are affected by seasonal river stage changes, as well as by diurnal tidal influences, with decreasing degree of influence with increasing distance from the river and shallower groundwater depths. Groundwater gradients within the shallow system are generally steep immediately adjacent to the river and flatten out away from the riverbank. The shallow flow system discharges to the river as surface seeps and subsurface discharge in near-shore areas.

The permeability of the FFA materials is variable within the shallow flow system, but generally is relatively low. Thus, fluxes to the river from shallow flow system are low. The presence of low-permeability features, such as silt and clay dikes constructed to retain hydraulically emplaced dredge fill, cutoff walls and retaining walls, may act to impede groundwater flow in the shallow system, resulting in higher groundwater levels and steep shallow groundwater gradients near the shore. Because of the generally low permeability of the shallow FFA sediments and the presence of these low-permeability features, preferential pathways (human-made and natural) influence the discharge of groundwater to the river.

Light non-aqueous phase liquid (LNAPL) spills are present only within the shallow flow system. Dissolved chemicals associated with upland releases are present in the shallow flow system. Dissolved plumes may be affected by vertical hydraulic gradients, which may cause vertical migration of the dissolved constituents. The shallow system also appears to influence the effect of DNAPL releases by retaining a portion of the released volume through spreading and retention in or along less permeable sediments. These stratigraphic controls can limit the depth of downward migration of DNAPL.

Intermediate Flow System

The intermediate flow system occurs within thicker sequences of the fine-grained alluvial sediments of the FFA. Groundwater in the intermediate system discharges to the Willamette River below the river surface to deeper portions of the river, with discharge focused at the locations where more permeable strata (typically sand) may intersect the river. Horizontal hydraulic gradients within the intermediate flow system tend to be flatter near the river than the shallow system, and thus high river stages and tidal changes may exert a greater influence on fluxes from the intermediate system to the river by further flattening or perhaps reversing the gradient locally.

The intermediate flow system is particularly relevant for groundwater transport of chemicals to the river where DNAPL is present or where chemical densities, preferential pathways, or downward gradients could potentially allow dissolved chemical constituents to penetrate into the deeper units. The intermediate flow system is the most likely mechanism that would allow for groundwater discharge into the sediments present in the deeper portions of the Willamette River. However, most groundwater chemical plumes identified in the upland areas of the ISA do not occur within the intermediate flow system.

Deep Flow System

The deep flow system occurs within the CGF and basalt interflow zones of the CRBG where the CRBG is present near the surface on the west side of the river. Groundwater in the deep system discharges to the Willamette River only in deeper portions of the river, with discharges focused at the locations where the gravels and/or basalt interflow zones are near or intersect the river sediments (Figure 2-1).

The CRBG ceases to play a role in this flow system on the east side of the river. The flow system becomes strongly affected by the Columbia River on the east side of the ISA with increasing distance from the Willamette River. The CGF is generally highly transmissive; however, gradients may be relatively low. Seasonal gradient reversals are known to occur during periods of high river stages. Where near the river, the connection and thus response to river stage changes is expected to be great.

The deep flow system is not anticipated to play a significant role in groundwater contaminant transport from the upland areas to the river within the ISA because the majority of contaminants in groundwater are not present within this system.

2.1.4 Processes Governing Discharge of Groundwater to the ISA

Generally, groundwater flow adjacent to the ISA is toward the river. In the absence of preferential pathways, groundwater flow to the sediments and river will be diffuse along the length of the interface of each flow system with the river. However, permeability contrasts of several orders of magnitude can be expected in the FFA where alluvial processes create lenses and channels of sand within or surrounding finer-grained materials. The result of these permeability contrasts is that groundwater discharge will tend to be heavily influenced by the location and geometry of higher permeability layers (e.g., sands) in relation to the river.

Discharge from the shallow water-table groundwater system will tend to be focused at or below the river/shore interface. Low river stages expose zones of focused discharge as seeps along the bank where the shallow groundwater surface intersects the ground surface. Preferential pathways, including coarse backfill (e.g., around utilities), historic stream channels, or sand/gravel layers focus groundwater flow, particularly where they occur in predominantly fine-grained sediment sequences in the shallow groundwater system. The majority of discharge to the river generally occurs where these preferential pathways intersect the riverbank. Full gradient reversals between the river and the shallow groundwater system are rare and likely localized near the bank because of the relatively high groundwater levels within the shallow groundwater system in the upland areas and resultant steep hydraulic gradients along the riverbank. However, very high river stages tend to reduce and may, in some areas, even temporarily reverse the shallow groundwater gradient locally. The groundwater flow regimes of all of the flow systems show seasonal patterns related to seasonal river stage and precipitation variations.

The gradient and resultant flux from these systems fluctuate with seasonal river stage changes, with temporary flow reversals occurring during seasonal high river stage events. Diurnal stage changes also result in temporary gradient and thus flow changes, particularly where the degree of connection between the river and adjacent aquifer is greater. Discharge of these deeper groundwater flow systems through the river sediments to surface water is controlled by (1) the permeability contrast between the sediments and underlying aquifer, and (2) the difference between the hydraulic head in groundwater at the aquifer/sediment interface and the river stage, which determines hydraulic gradient.

2.1.5 Groundwater/Surface Water Transition Zone

The groundwater/surface water transition zone (Transition Zone) is the interval where both groundwater and surface water comprise some percentage of the water occupying pore space in the sediments. The physical and biochemical properties of water within the Transition Zone reflect the effects of mixing between groundwater and surface water that occurs within the sediments. The Transition Zone is significant to the RI/FS because it is the location where important chemical and biological transformation processes occur that affect the properties of chemicals that may be present in groundwater, and it encompasses the sediment bioactive zone where benthic infaunal ecological receptors reside.

The zone of mixing between groundwater and surface water that defines the size of the Transition Zone exhibits temporal and spatial variability due to changes in gradients between the surface water and groundwater. The depth and degree of mixing is anticipated to be relatively small in shallow river sediments that are in contact with the shallow groundwater flow system. In these areas, relatively high groundwater hydraulic heads within the shallow groundwater flow system adjacent to the river dominate the river stage fluctuations. High river stages will change the relative hydraulic gradient and thus reduce the discharge rate from the shallow groundwater flow system through the sediments, but will not likely result in a significant overall increase in the depth of mixing of surface water with groundwater. Groundwater is expected to comprise a greater percentage of the water in the shallower water bioactive zone than deeper water locations where the deeper flow systems discharge to the river.

2.2 HYDROLOGY

River stage and currents in the LWR and Portland Harbor are influenced by hydrologic conditions in both the Willamette and Columbia rivers, and are further affected by the operations of federal and non-federal dams along these two rivers. River stage refers to the height of the river measured relative to a specific elevation or "datum." A variety of vertical datums are used in the Portland Harbor region, and these are discussed below. Definitions of regional datums and other hydrologic terms are also included in the Glossary of Terms (Section 11).

2.2.1 Regional Datums

Current or historical bathymetric and topographic data may be referenced to a variety of vertical datums in Portland Harbor. The bathymetric data collected as a part of this RI/FS are presented relative to the **North American Vertical Datum of 1988 (NAVD88)**. This vertical datum is the national standard geodetic reference for heights and was selected for this project because it is a level datum and is easy to use with global positioning systems (GPS). NAVD88 is a fixed datum derived from local mean sea level observations at Father Point/Rimouski, Quebec, Canada. NAVD88 replaced NGVD29/47 as the national standard geodetic reference for heights.

The **National Geodetic Vertical Datum of 1929 through the Pacific Northwest Supplemental Adjustment of 1947 (NGVD29/47)** is a fixed datum adopted and adjusted in 1947 as a national standard geodetic reference for heights prior to June 24, 1993 and is now considered superseded by NAVD88. NGVD29 is sometimes referred to as Sea Level Datum of 1929 or as MSL on some early issues of U.S.Geological Survey topographic quads. NGVD 29 was originally derived from observations at 26 long-term tide stations in the U.S. and Canada. Data referencing MSL as the vertical datum in the Portland Harbor is technically on NGVD29/47.

The **Columbia River Datum (CRD)** is used as the chart datum for the lower Willamette River. CRD is a reference plane established by the Corps in 1912 by observing low water elevations at various points along the Columbia and Willamette rivers (USACE 1966). Consequently, the CRD is not a fixed/level datum but slopes upward as one moves upstream. The CRD is used upstream of RM 24 on the Columbia to the Bonneville Dam and on the Willamette River to Willamette Falls. Mariners can obtain the depth on a chart and apply tide or river-level gauge readings, relative to CRD to compute actual water depth at the time of sailing. Low water values are used for navigation charting to provide conservative depth values in the event accurate tide data are not available to the mariner.

These three datums, NAVD88, NGVD29/47, and CRD, are the major ones used on maps and charts of Portland Harbor. The relationships or conversion factors between them are shown in Table 2-1 for the LWR to about RM 16 (Ross Island). This conversion table is also included on all LWG project bathymetry maps. In the lower Willamette, elevations reported relative to the CRD are approximately 5 feet less than NAVD88 elevations (e.g., the –15 foot NAVD88 contour on LWG bathymetry maps equates to a –20 foot CRD elevation).

Water level (river stage) data measured by the Morrison Bridge gauge (RM 12.8) are recorded as the **Portland River Datum (PRD)** and are 1.55 feet above NGVD29/47 (USACE 1991). The CRD is 1.85 feet above NGVD29/47 at the Morrison Bridge. On December 27, 2001, David Evans and Associates, Inc. (DEA) confirmed the relationship between this gauge and the CRD by running a differential leveling circuit from a nearby control monument used in the control network for the Willamette multibeam surveys. This survey confirmed that the Morrison Street staff gauge reports water levels 0.30 foot above CRD, as defined by the Corps (1991).

The river stages discussed below in Section 2.2.2 are the directly measured Morrison Bridge gauge levels and are therefore reported as PRD elevations in feet. To convert from PRD to CRD, subtract 0.3 foot from the reported river level.

2.2.2 Willamette River Stages

The Columbia River drains a large segment of the northwestern United States and parts of western Canada. The basin is so large that isolated events such as rainstorms may have little or no effect on river flow. In its natural state, high flows on the Columbia River are most influenced by snow melt, which takes place in the basin during the spring months. This results in high water typically occurring in late May or early June followed by receding water levels until the rains begin in late fall.

Lowest water on the Columbia River typically occurs in the months of October or early November, reflecting a lack of precipitation and snowmelt in the basin during the summer months. With the onset of winter rains and snow, runoff will vary during the winter months until the snowmelt takes place in the spring leading to the high water period described above.

The Willamette River is a major tributary of the Columbia River and flows into the river at Columbia River mile 103. Lowest water in the Willamette, as in the Columbia, typically occurs between September and early November prior to the initiation of the winter rains. With the onset of the rains, flows in the Willamette will generally increase, sometimes in rapid (several days) response to regional storms. The record winter floods (e.g., 1964 and 1996) occurred when a period of heavy snowfall at lower elevations was followed by a period of warming and heavy rains. The combination of the snowmelt and rain leads to exceptionally high runoff that occurs rapidly due to the small size of the basin as compared, for example, with the Columbia River basin.

Figure 2-2 shows plots of the mean daily river stage data (reported in feet, PRD) measured by the U.S. Geological Survey (USGS) gauge (#14211720) on the Morrison Bridge in Portland near RM 12.8, from 1973 through mid-August 2003[3]. The seasonal water level trends described above are evident in these plots. Low water typically occurs during the regional dry season from August to November. Winter (November to March) river stage is relatively high but variable due to short-term changes in precipitation levels in the Willamette basin. Finally, a distinct and persistent period of relative high water occurs from late May through June when Willamette River flow into the Columbia is slowed during the spring freshet by high-water stage in the Columbia River.

The effect of the multipurpose dams on the Columbia River and its tributaries has been to generally reduce the spring high water flows through ponding of the excess water to the extent permitted by the capacity of the reservoirs at each of the dams. Starting in late summer, this stored water is released, which increases flows above the low flows that would otherwise occur. By winter, these reservoirs have been drawn down and the reservoir capacity is used to take the peak off of winter flows and to optimize the generation of electricity.

There are 13 federal reservoirs on the Willamette River and its tributaries, having a combined storage capacity of over 1.6 million acre-feet. These reservoirs reduce the river flow during the winter snow and rain events by storing water (Table 2-2). With each major storm, water is stored and then released at the end of the storm to smooth out the flow of the river. During persistent rainy periods and/or during exceptionally large precipitation events, the storage capacity may be exceeded, and additional flow entering the system leads to flooding as occurred in 1964 and 1996. During these flood events, water flow in the river can be up to 50 times greater than the flow during low-water periods. Late in the winter, after the probability of a major flooding event has passed, the reservoirs are filled to capacity. These reservoirs are used for

[3] Data obtained from the U.S. Army Corps of Engineers (Portland District) Reservoir Regulation and Water Quality Section web site (http://www.nwd-wc.usace.army.mil/cgi-bin/DataQuery). This site notes that these “data have not been verified and may contain bad and/or missing data and are only provisional and subject to revision and significant change.” The data are used here only to illustrate long-term relative trends in the Willamette River stage at Portland. No data were available for 1991 and 1992.

recreation during the summer and are drawn down in the fall to supplement natural low flows and to provide storage capacity in preparation for the flood season.

Water levels and currents in the LWR can be influenced by the Columbia River in several ways. The most apparent influence occurs during spring when high flows from the Columbia River increase the hydraulic head at the confluence of the two rivers and causes the Willamette River flow to be detained (Figure 2-2). When this occurs, currents in the Willamette are much reduced due to the elevated river stage in the Columbia River. As the Columbia River drops, the Willamette water level will also drop and flows will increase to more typical conditions.

A less obvious influence can occur in the winter when the Willamette River is in flood. The flows on the Columbia River can be held back by its dam system, which has the effect of lowering the backwater effect of the Columbia and thus dropping the levels in Portland Harbor below their typical condition. This mechanism was used in the 1996 flood to reduce the flood levels of the Willamette in Portland Harbor.

Compounding the complexity of the influence of two separate river systems and drainage basins, the Portland Harbor reach is also affected by tidal action. The tidal range at the Pacific Ocean is approximately 8 feet and there are two high tides and two low tides daily. The tidal “wave” comes up the river and when the Willamette River is at a low stage, the tidal action can influence river levels by up to 3 feet in Portland Harbor. These tidal fluctuations can result in upstream flows in the Portland Harbor during times of extreme low discharge combined with a large variation in tide levels, which can occur in late summer to early fall**.** As river stage rises, the tidal effect is gradually dampened and disappears at river levels around 10 feet CRD.

2.2.3 Willamette River Flows

Velocity data for the LWR consist mainly of data collected over the years by the USGS. The USGS report, Water Discharge Determinations for the Tidal Reach of the Willamette River from Ross Island Bridge to Mile 10.3, Portland, Oregon, (Dempster and Lutz 1968), mentions a total of 127 discharge measurements that were conducted during the period from July 1962 to January 1965. The USGS measured velocities using a Price current meter suspended from the Broadway Bridge near RM 11.7 and the Ross Island Bridge near RM 14 (see Map 1-1). Stream flow conditions varied from low tidal-affected flows to the near maximum flood of record during December 1964. Measured cross-sectional mean velocities ranged from a maximum of 8 feet/second downstream during the December 1964 flood to a low upstream velocity of nearly 1 foot/second during a tidal cycle on October 15-16, 1963 (Demptser and Lutz 1968).

From October 1972 to September 1994, the USGS maintained an acoustic velocity meter with water stage and velocity index recorder at the Morrison Bridge gauge near RM 12.8. During that time period, rating curves were periodically updated with velocity measurements at the gauge location over a range of flow conditions. Since October 1994, the gauge has been jointly operated with the Corps and measures un-verified stage only (Lee 2002).

On January 14, 2000, the USGS collected isolated transects of velocity data using a vessel-mounted Acoustic Doppler Current Profiler (ADCP). Transects were collected upstream of the ISA in a relatively narrow stretch of the river at RM 12.8 (just downstream of the Morrison Bridge; see Map 1-1), and in a broader stretch of the river in the ISA near RM 4.1 (Barrett 2002; Wood 2002). According to the upstream Morrison Bridge gauge, the estimated discharge for January 14, 2000 was 99,000 cfs.

Additional ADCP data were collected by DEA for the LWG during a high water event on April 19, 2002 (DEA 2002b). The ADCP was mounted on a 30-foot survey vessel, and transects were taken at RMs 1, 2, 2.5, 3.1 (Multnomah Channel), 4, 4.6 (into T-4 Slip 3), 5.8 (St. John's Bridge), 6.3 (off Gasco), 6.8 (into Willamette Cove), 7.8 (off Willbridge Terminal), 8 (from Coast Guard Station, across shipyard to west bank), Swan Island Lagoon (2 short transects - one across mouth, one at upper end), 9.6, 10, and 11 (see Map 1-1). The river stage at the time of the data collection was approximately 11.6 feet CRD at the Morrison Street Bridge (DEA 2002b).

Water velocities obtained from the ADCP survey ranged from an upstream velocity of nearly 1 feet/second (upstream flow in back eddy) to a downstream velocity of 2 feet/second. Flows across the transects were computed at approximately 70,000 cfs above Multnomah Channel and approximately 35,000 cfs below Multnomah Channel. The Willamette flow on April 19, 2002 was roughly double the average Willamette discharge rate of about 32,000 cfs. Table 2-3 summarizes ADCP transect time, location, and approximate total flow.

Figure 2-3 presents historical daily mean flows from USGS gauge #14211720 located at the Morrison Street Bridge on the Willamette River in Portland. Data from October 1972 to September 1994 were computed using velocity measurements from an acoustic velocity meter. Data after September 1994 are based on estimated flows by the USGS. No estimates were located after 2001. The USGS plans to install an acoustic velocity meter on the Morrison Street Bridge during the 2003 water year, which should be operational by summer 2003 (Kittelson 2003).

Figure 2-3 references the 70,000-cfs flow under which the 2002 ADCP survey was conducted. Average flow ranges from 58,000 cfs in winter (December through March) to 9,000 cfs in late summer (July and August). Peak events can trigger flows in excess of 150,000 cfs, with maximum flows over 400,000 cfs (1996 winter flood).

Figure 2-4 is a vector plot of the water-column-averaged velocity, magnitude, and direction at transect 4 at RM 3.1, located at the entrance to the Multnomah Channel. Figure 2-5a illustrates a color plot of the velocity magnitude, and Figure 2-5b presents the projected velocity perpendicular to the transect. These data indicate that close to one-half of the total flow (35,000 cfs) was being diverted down Multnomah Channel during the ADCP measurement period.

Parameters that would affect total flows and the amount of flow diverted down Multnomah Channel include relative stage of the tides in St. Helens and Portland, flow in the Columbia River, and Willamette River flow into the Portland Harbor. The velocity depicted in Figure 2-5b is the result of only using the velocity component perpendicular to the transect. This is further illustrated by the vector plot in Figure 2-4, which depicts the diversion of flow into Multnomah Channel. Flow into the Multnomah is likely greatest when low river stages at St. Helens and the Columbia correspond with high stages in the Willamette; this was the situation during the ADCP survey on April 19, 2002. It is unclear how often this occurs, but the inter actions of these factors over time will be evaluated as part of the hydrodynamic modeling of the system. Figure 2-5b also reveals some variation in velocity with depth in the shallow water entrance to Multnomah Channel on the west side of the river and a back eddy effect on the east bank.

Figure 2-6a presents ADCP data at transect 11 at RM 8, just downstream of Swan Island and the Portland Shipyard. Both the vector plot (Figure 2-6a) and velocity profile (Figure 2-6b) reveal a sharp drop in velocity behind Swan Island and a small back eddy into Swan Island Lagoon. The velocity profile in Figure 2-6b also illustrates some vertical structure with increased flows in the upper water column in mid-channel.

Figure 2-7a presents the measured ADCP data at transect 14 at RM 9.6 across the deep dredged hole off of Swan Island. An increase in the water column average velocities can be seen in Figure 2-7b. A back eddy can be observed in both the vector plot and the velocity profile. The velocity profile also shows strong near-bottom velocities in the hole with increased velocity toward the water surface.

2.3 BATHYMETRY

As part of the pre-AOC RI/FS studies, a multibeam bathymetric survey was conducted of the LWR from the confluence with the Columbia River to RM 15.6 (upstream end of Ross Island; see Map 1-1). The primary goal of the survey was to develop an accurate, baseline, riverbed elevation database for this portion of the LWR. This precise bank-to-bank bathymetric survey was conducted by DEA between December 13, 2001 and January 14, 2002, during the winter period of relatively high water. The vertical accuracy of the water depth measurements was specified at less than or equal to 0.5 foot (NAVD88), and the horizontal accuracy was set at less than or equal to 1 meter. The data were processed using a 1-meter grid size to generate a digital terrain model, and the survey results were plotted in both hillshade and contour formats. A bathymetry report detailing the methods used and the survey results has been provided to EPA under separate cover (DEA 2002a).

Map 2-2 provides a summary of the baseline bathymetric survey results and shows LWR bed elevations as of January 2002. [Higher resolution maps are provided in DEA (2002a).] From RM 0 to 11.6 (Portland Harbor), elevations in the federal navigation channel are generally 40 to 50 feet in depth. Several deep holes, particularly off Terminal 4 and Swan Island, reach 70+ feet in depth; these are borrow areas dredged in the past to provide fill to create the adjacent uplands. Most of the ISA is characterized by relatively steep slopes from the riverbank to the authorized channel depth (- 40 feet). The broadest gradually sloping areas that extend from 0- to about 30-foot depth occur off Sauvie Island from RM 0 to the Multnomah Channel, at the head of Swan Island Lagoon, and along the west side of the river between Willbridge Terminals and Terminal 2. Upstream of the federal channel, river bed elevations are more variable and generally follow the river bed morphology, with the deeper areas (40+ feet) occurring on the outside of the river bends and scour features evident downstream of the downtown Portland bridge footings. The side channel east of Ross Island Lagoon is a relatively shallow area (< 20 feet), while the main channel west of Ross Island extends to 60-foot depth in places.

A second bathymetry survey was conducted in the summer of 2002 (DEA 2003). Comparison of the time-series bathymetry survey results allows areas of riverbed that shoaled or scoured between December 2001 and September 2002 to be identified. These results are presented and discussed in Section 2.6.

2.4 PHYSICAL CHARACTERISTICS OF SEDIMENTS

The physical properties of sediments yield significant information regarding the physical dynamics of the river system. Coarse-grained sediments are generally found in erosional areas where water currents remove fine particles from the sediment, while fine-grained sediments typically occur in depositional areas where water velocities are low enough to enable the settling of fine-grained particles.

Grain-size distribution of sediments throughout the LWR was measured in September 2000 during a Sediment Trend Analysis (STA®) survey (Map 2-3) (GeoSea Consulting 2001). Surface sediment sampling was attempted at 935 locations from the Willamette Falls at RM 26.5 downstream and into the Columbia River. Of the 935 sampling stations, 99 were classified as "hard ground," meaning sediments could not be collected after three casts of the grab sampler. As noted by the authors, the actual ground may not have been hard (i.e., bedrock), but rocks and other debris may have prevented the grab sampler from closing.

The distribution of sediment grain sizes in the LWR from this survey shows a predominance of "hard ground" in the upstream reaches of the river south of Ross Island. This pattern may be due to outcroppings of Columbia River basalts in the riverbed in that region (GeoSea Consulting 2001), as well as increased flow velocities due to a smaller cross-sectional area of the river as compared with the ISA. Natural sediment composition in the LWR is variable. Sand and gravel particles are predominantly quartz, feldspar, or lithic fragments. Lithic fragments are typically basalt.

The grain-size distribution of sediments in the LWR becomes finer downstream, especially where the river widens and/or where water has an opportunity to pool. In general, sandy sediments dominate the riverbed upstream of RM 11, while surface sediments below RM 10 are predominantly silt (Map 2-3). Surface sediment texture between RM 10 and 11 is transitional between the upstream sandy and downstream silty areas. In general, silts dominate surface sediments in Portland Harbor, with localized areas of sandier material occurring at narrower portions of the river, such as in the navigation channel between RM 5 and 7, and at the mouth of the Willamette River where Columbia River sands may be moving into the LWR. Sheltered areas throughout the LWR, such as the Ross Island and Swan Island lagoons, are generally characterized by finer-grained sediments than the adjacent main channel. Some coarser sediments are found near bridge supports in some nearshore or berthing areas; these are likely the result of vessel propeller wash (prop wash). As part of the LWG's pre-AOC studies for this RI/FS, a December 2001 sediment-profile imaging survey of the Willamette River from Ross Island to the Columbia River documented similar grain-size distribution patterns in this stretch of the river (SEA 2002f; see Section 2.5).

2.5 SEDIMENT TRANSPORT AND TRANSPORT REGIMES

River currents, vessel movements, wave activity, and the supply of sediment affect sediment transport in the LWR. Finer-grained sediments (silts and clays) have lower settling velocities and thus tend to remain suspended in the water column longer than coarser-grained materials (ASCE 1975). The quantity of suspended sediment load varies seasonally, with higher quantities delivered by storm or high flow events. USGS measures suspended sediment concentrations at the Morrison Bridge (RM 12.6) gauge approximately once a month, in addition to a few surveys have been conducted at various locations in the Portland Harbor during specific high flow events (Lee 2002).

Figure 2-8 is a composite of long-term suspended sediment data collected at the Morrison Bridge and some short-term, high-flow, suspended sediments measurements upstream of the St. Johns Bridge, which depicts the tendency for increased sediment concentrations in the water column during high flow events. In general, however, the Willamette has relatively low suspended loading during most flow conditions. Furthermore, most of the suspended sediments coming into the Portland Harbor are relatively fine-grained. Some percentage of the sediments remains in suspension and passes through the Portland Harbor, while the remainder tends to settle in depositional areas. Subsequent redistribution of sediments may occur more through bedload transport than by erosion, resuspension, transport, and deposition.

Depending upon the hydraulic conditions during high water events, sediments can be deposited, transported through, or scoured in the lower harbor. For example, with a high Willamette River discharge and a low Columbia River stage, velocities through the Portland Harbor will be high, and critical transport velocities of fine-grained sediments will be exceeded, thus transporting material downstream either as bedload or as resuspended sediments in the water column. Conversely, if the high discharge event on the Willamette River is coincident with a high stage on the Columbia, the velocities in the Portland Harbor will be lower, and suspended or bedload sediments entering the harbor are likely deposited there. Localized and sporadic anthropogenic disturbance or riverbed sediments (e.g., dredging, prop wash) provide an additional mechanism of reintroducing sediments into the water column. Their transport fate would be a function of LWR flows at the time of their disturbance.

A review of a series of historic bathymetric survey overlays of the navigation channel (RM 0 to 11.6), conducted two to three times annually from August 1990 to May 2001 by the Corps, Portland District, indicates that, as expected, channel riverbed elevations are variable in places (Map 2-4). The locations of federal and private dredging areas are also shown on this map, and significant deposition within these deeper areas is evident over time (e.g., near RM 11, between RM 9 and 10, near RM 5, and between RM 2 and 3). The historic bathymetric data evaluation also estimated change in sediment volume by river mile from survey to survey. These results are graphed and presented for all river miles in Appendix D. Figure 2-9 shows the volume changes over time for two segments, RM 4 to 5 and RM 7 to 8. These approximations suggest that a significant volume of sediments is deposited and subsequently transported from different portions of the navigation channel over time.

Although a few models have been developed to analyze water levels, velocities, and water quality in the LWR, no numerical models have been developed for Portland Harbor to specifically examine sediment transport.[4] The September 2000 STA® (GeoSea Consulting 2001), however, provides a broad-scale picture of sediment movement from the Willamette Falls downstream to the river's convergence with the Columbia. The STA® methodology statistically examines the relative changes in grain-size distributions that occur along transport paths. Maps are produced that indicate the patterns of sediment transport and areas of erosion, equilibrium, and accretion (Map 2-5).

The STA® analysis concluded that sediments in transport or those discharged from outfalls into the system from Willamette Falls downstream to about the Fremont Bridge (RM 11) are essentially in dynamic equilibrium or "conveyor-belt" movement downstream (Map 2-5). Below the Fremont Bridge, sediments are finer and the transport environment becomes depositional. The analysis concluded that the main stem of the river between RMs 7 to 10 is a depositional sink for sediments.

[4] The LWG is planning to develop a hydrodynamic and sediment transport model of the LWR as part of this RI/FS (see Section 2.6.2).

Downstream of this reach from about RMs 7 to 3.5, another conveyor-belt sediment transport regime is present. From RMs 3.5 to 1, the transport environment is classified as a mixed case (i.e., there are alternating periods of deposition and erosion). Finally, where the Willamette enters the Columbia River system at RMs 0 to 1, the STA® analysis suggests that dynamic equilibrium and/or erosion dominate this portion of the river.

The STA® analysis infers sediment transport dynamics from surface sediment grain-size distributions for the time frame represented by the surface grab samples, which is unknown and likely varies spatially throughout the system. The effects of infrequent, large-scale events, such as 10+ year floods, on sediment movement within and out of the LWR have not been described, although the historical data shown in Figure 2-9 and Appendix D suggest that the February 1996 flood event resulted in significant deposition of sediments in many portions of the navigation channel.

The results of STA® survey and the historic bathymetric data evaluations were compared in SEA (2002b). This comparison was limited to the navigation channel within the ISA and reached the following conclusions:

- The channel in the ISA from approximately RM 9 to approximately RM 7 is a net depositional area, while the rest of the ISA channel area (from RMs 7 to 3.5) is predominantly a system that is in dynamic equilibrium, with localized areas of deposition and erosion.
- Deposition rates in depressions and in the depositional area from RMs 7 to 9 consistently fall between the range of 0.5 to 1 foot /year; most of this deposition occurs in bathymetric lows (commonly associated with dredging or borrow areas) and along the inside bends of the river.
- Erosion is most consistent outside of the ISA, but occurs within the ISA in localized areas such as along the outside bends of the river. Episodic erosion occurs based on short-term hydrologic events; however, periodic dredging can obscure actual events of erosion in the bathymetric depth difference analysis.

Two other pre-AOC efforts, the December 2001 multibeam bathymetric survey and sediment-profile image (SPI) surveys (DEA 2002a; SEA 2002f) from Ross Island to the Columbia River, provide results that are consistent with the broad sediment movement patterns described by the STA®/bathymetry data comparison. In addition, these results provide information on surface sediment dynamics in areas beyond the ISA and in particular, in shallow, nearshore areas outside of the navigation channel. Based on the mapped SPI/bathymetry results, eight major benthic condition zones were defined in the Willamette from Ross Island downstream (Map 2-6).

Seven of these zones occur upstream to downstream in the main stem or channel of the river (deeper than –20 feet CRD), where the sediment transport regime appears primarily controlled by physical factors, specifically river shape, width, and flow. These factors appear to govern the types of sediments seen within the main channel, substrate stability and heterogeneity, and possibly the soft-bottom benthic community structure. The eighth zone, which occurs in nearshore areas (all areas shallower than –20-foot-depth CRD along both margins of the river), represents areas in which the conditions observed at any particular location vary as a function of small-scale variations in river morphology/dynamics, bank treatments, and river use. The general characteristics of each benthic zone delimited in Map 2-6 are shown in Table 2-4.

Overall, the evaluation of historic bathymetry data and the results of the STA® and SPI surveys produce a consistent picture of sediment transport regimes in Portland Harbor. These data and the direct measurements of elevation changes discussed below form the basis of portions of the physical CSM detailed in Section 5, and provide an important foundation for scoping key elements of the RI such as the distribution of chemicals in sediments.

2.6 RIVERBED ELEVATION CHANGES (2001-2002)

The second bathymetric survey conducted by DEA in the summer of 2002 was to directly measure seasonal changes in riverbed elevations that had occurred since the previous winter (DEA 2003). The survey was conducted in two phases: RMs 2 to 11 were surveyed between July 3 and 18, 2002, and RMs 0 to 2 and RMs 11 to 15.6 were surveyed between September 16 and 20, 2002. The summer 2002 data were processed in the same manner as the winter 2001/2002 data (Section 2.3) and updated contour and hillshade maps were generated. In addition, a set of elevation difference maps that show the riverbed elevation changes that occurred over the 9-month period from December 2001 to September 2002 were generated (Map 2-7a-k).

As shown in Map 2-7, the elevation change maps were created by overlaying the 1-meter cells from each survey and subtracting the winter 2001/2002 data from the summer 2002 data to generate a direction and magnitude of change for each cell. The vertical resolution of the multibeam survey overlay was +/– 0.25 foot, so cell comparisons that show positive or negative change less than or equal to 0.25 foot represent no discernable change in riverbed elevation.[5] Because the winter 2001/2002 data were subtracted from the summer 2002 data, negative elevation changes (shallower in summer compared to the previous winter) indicate shoaling and positive elevation changes (deeper in summer compared to the previous winter) indicate deepening. In Map 2-7, the no-change areas are shaded gray, while shoaling

[5] The survey vertical accuracy specification of ≤ 0.5 foot was exceeded for both individual surveys. An analysis of bathymetric change data indicated that the vertical resolution of the survey overlay was ± 0.25 foot for approximately 80% of the data (DEA 2003). Therefore, this interval was used as the no-change category.

areas (negative change) are shown in yellow to orange shades, and areas that deepened (positive change) are shown in blue shades.

As shown in Maps 2-7a-k, sediment accretion and erosion occurred in various parts of the LWR between December 2001 and September 2002. Some general sediment movement patterns include:

- Areas of shoaling and deepening occur more frequently in off-channel, shallow nearshore areas than in the main navigation channel.
- River zones that were inferred to be higher energy zones based on the STA® and SPI summarized above (e.g., above RM 12 and between RMs 5-7) show numerous small-scale changes from bank-to-bank.
- Zones that were inferred to be lower energy (e.g., RMs 3-5, 7-9) show fewer small-scale changes in the channel.
- In some places, bedforms (e.g., at RM 5-6 and RM 11-12) can be seen propagating downstream (alternating high and low spots).
- Deposition or in-filling of some former in-channel dredged or borrow areas (e.g., at RMs 2, 5.2, and 9-10) is evident.
- The most extensive stretch of nearshore deepening extends along the west side of the river from RMs 0 to 3; this appears to be a natural sediment erosion pattern.
- The most extensive stretch of nearshore shoaling extends along the west side of the river from RM 4 to 5; this appears to be a natural sediment shoaling area.
- Bridge footings create localized areas of deep scour and accretion (e.g., the Railroad Bridge at RM 7).
- Many areas of deepening appear to be closely associated with pier structures, berthing areas, and slips (e.g., Terminal 4, Portland Shipyard, Willbridge Terminals); it is likely that much of this sediment movement is the result of anthropogenic factors (e.g., prop wash).
- Some recently dredged areas (e.g., at RM 10 off Terminal 2) are evident.

2.6.1 Patterns in the Distribution of Shoaling and Deepening Areas in 2002

The bathymetry change data shown in Map 2-7 are tabulated by river mile in Table 2-5a for shallow nearshore areas and in Table 2-5b for the deeper main channel areas. The definition of the nearshore and channel areas is based on the results of the

December 2001 SPI survey (SEA 2002f). As indicated in Section 2.5, the sediment transport regimes inferred from the SPI results in the deeper portions of Portland Harbor (navigation channel and lower channel slopes) differed notably from those inferred for the nearshore areas (upper channel slopes, off-channel benches and beaches). The division between these "channel" and "nearshore" areas was delineated by the –15-foot NAVD88 contour that equates approximately to the –20-foot CRD contour in the survey area. The nearshore area defined by the NAVD88 15-foot contour is shown in Map 2-8.

Table 2-5 lists the numbers of square meters in each river mile that show no change, shoaling, and deepenin*g* across the full range of vertical change intervals observed. The no-change category is defined as +/– 0.25 foot based solely on the vertical resolution of the overlain bathymetry measurements. The percentage of the area within each river mile that fits into each of these three categories is shown at the bottom of Tables 2-5a and 2-5b, and cumulative shoaling and deepening percentages by change interval are tabulated on the right. The percentage of the area within each river mile showing no change, shoaling, and deepening is graphed on Figure 2-10. Several general trends are evident:

- First, consistent with the patterns on the bathymetry change maps, the proportion of each river mile that shows no change (gray bars) is substantially greater in the channel areas (Figure 2-10b) than nearshore areas (Figure 2-10a).
- Second, in nearshore areas (Figure 2-10a), the percentage of the river exhibiting shoaling (green bars) peaks between RMs 4-5 and 10-11; these are reaches identified as "depositional zones" based on the SPI survey data (SEA 2002f). Channel shoaling peaks are less distinct than the nearshore peaks, but also occur in the "depositional zones" at RMs 1-2, 4-5, and 9-10, as well as in an upstream area around Ross Island (RM 14-15.7).
- Finally, in the nearshore areas, the percentage of the area that deepened (red bars) peaks at RMs 0-3 and 11-13. In channel areas, the peaks in deepening occur at RMs 2-3, 5-6, 11-13 and 14-15.7. The upstream (RMs 11-13) and mid-reach (RMs 5-6) areas were identified as "transport zones" based on the STA® (GeoSea Consulting 2001) and SEA (2002b) results. The peak in deepening in the nearshore downstream areas (RMs 1-3) appears to reflect the large, contiguous zone of erosion that is evident along the west side of the river from RMs 0 to 3 (Map 2-7a and 2-7b).

The data compiled in Tables 2-5a and 2-5b allow the total percentage channel and nearshore areas that either deepened or shoaled to be quantified.

Channel Areas. Across all channel areas combined, approximately 65.9% of the riverbed shows no change in elevation between the two surveys, while 22.5% of the area deepened measurably and 11.6% shoaled. The cumulative percent of the channel area that is shoaling and deepening by vertical change interval is also provided in Table 2-5b. For both shoaling and deepening, over 90% of the cells that exhibit vertical change show change that is less than or equal to 1 foot in magnitude, and over 98% of the cells show vertical change that is less than or equal to 2 feet. When the no-change cells are included in the calculation (i.e., the sum of the no-change cells and the shoaling/deepening cells ≤ 1 foot over the total cell count), only 2.8% of the total area of the channel shows vertical change (either shoaling or deepening) greater than 1 foot. This represents a total channel area of about 260,000 m^2.

Nearshore Areas. Across all nearshore areas combined, approximately 43.3% of the riverbed shows no change in elevation between the two surveys, while 40.3% of the area deepened measurably and 16.4% shoaled. The cumulative percent of the nearshore area shoaling and deepening by vertical change interval is shown in Table 2-5a. The magnitude and the extent of vertical change are greater in nearshore areas than offshore. Still, over 75% of the cells that exhibit vertical change show change that is less than or equal to 1 foot, and over 93% of the cells that show vertical change show change that is less than or equal to 2 feet. When the no-change cells are included in the calculation, the percentage of the total area of the nearshore riverbed that shows vertical change (either shoaling or deepening) greater than 1 foot is approximately 13.4%. This represents a total nearshore area of about 215,000 m^2.

2.6.2 Temporal Considerations

The vertical changes in riverbed elevations that were measured by the LWG cover an 8 to 9-month period from January to September, 2002. Because changes in riverbed elevations are assumed to be directly influenced by river flow, an analysis of river stage height data was also conducted. The 2002 river stage height year is included on each water year plotted in Figure 2-2 for comparison purposes. Visual examination of Figure 2-2 indicates that the January to September period in 2002 was relatively typical in terms of river stage heights compared with the same period in other years since 1973 for which there are relatively complete river stage data. The January to September 2002 river stage pattern was similar in magnitude to that observed in 1978-80, 1985, 1987, 1989, 1990, 1993, 1995, 2000, and 2003, notably less than the January to September river stages observed in 1974-76, 1981-84, 1986, 1996, and 1997-1999, and notably greater in magnitude than the river stages measured in 1973, 1977, 1988, 1994, and 2001. For the 30-year period from 2003 to 1973 only 28 year-to-year comparisons could be made because there are no data for 1991 and 1992. Based on those data, the 2002 river stages were either greater than or similar to the river stages observed in other years 57% of the time (16 years), and were less than the river stages observed in other years 43% of the time (12 years).

In reviewing the river stage data in Figure 2-2, note that LWR flood stage is +18 feet CRD (18.3 feet PRD), and the ordinary highwater mark in the LWR is approximately +15 feet CRD (15.3 feet PRD).

The patterns of sediment movement measured over the 8-9 month period in 2002 are consistent with the understanding of sediment transport regimes in the system based on the work conducted during the planning phases of the RI/FS (GeoSea Consulting 2001; SEA 2002b,f). In addition, the scale of the observed elevation changes is consistent with the annual depositional rates of 0.5 to 1 foot/year estimated by comparing historical dredge records from the navigation channel for the 10-year period 1990-1999 (SEA 2002b). Additional activities currently undertaken or planned by the LWG to verify and expand this understanding of the Portland Harbor physical system are listed below and discussed further in Section 7.1:

1. A third multibeam survey of the Portland Harbor was conducted in May 2003 to provide a third data set in the bathymetry time series. The riverbed elevation changes from winter 2001 and summer 2002 were compared with the spring 2003 data (SEA and DEA 2003). The spatial patterns and magnitude of bathymetric changes seen between May 2003 and the summer of 2002 were comparable to those described above for the period from the winter 2001 to the summer 2002.
2. A fourth multibeam bathymetric survey, including ADCP flow measurements was initiated in February 2004 following a relatively high flow (~ 140,000 cfs) event on the LWR. The riverbed elevations observed immediately following this event will be compared to previous survey data as a direct measure of riverbed elevation changes following a high energy event.
3. A hydrodynamic and sediment transport model of the LWR will be developed in 2004 pending approval of the proposed modeling approach described the modeling technical memorandum submitted to EPA in Febraury 2004 (West Consultants 2004). This model will be developed, calibrated, and validated using the physical data (e.g., time-series bathymetry, flow measurements, sediment characteristics) available prior to the Round 2 data collection efforts. The model will be refined based on additional physical data (e.g., sediment surface and core data) collected in Round 2. The model is designed to allow long-term predictions of sediment movement during hydrological events (i.e., floods) that will not likely be experienced during the RI/FS. Additional details on how the model results will be used in the RI/FS are provided in Sections 6 and 7 of this work plan.

2.7 DREDGING

Dredging records for the Portland Harbor were requested from the Corps, the Port of Portland, and private entities. Data for dredging projects from 1980 through 2001 were obtained from the Corps, Portland District, and from the Port of Portland and are compiled in Table 2-6. For federal and Port dredging projects, Table 2-6 lists the year dredging occurred, the dredging location, the purpose of the dredging, and the quantity of dredged sediment. Map 2-2 identifies the approximate dredging location for most events. For the purposes of presentation, dredging area boundaries have been grouped into two intervals (1980-1991 and 1992-present), in order of occurrence. However, the areas identified as private dredging on the figure are approximations of dredge borrow site locations. The dredge borrow sites were identified by comparing pre- and post-dredge hydrographic surveys of the sites. Some recently dredged areas are also evident on the bathymetric survey difference maps presented in Map 2-7a to k (e.g., the Port of Portland's Terminal 2 dredging prism just upstream and downstream of RM 10; Map 2-7g and 2-7h). A compilation of available dredging permits issued by the Corps, pending permit applications, or permits to be issued by the Corps during the implementation of the RI/FS will be included in the RI. This information will also include third-party permits.

Review of the data in Table 2-6 indicates that from 1980 to 2001 about 95% of the maintenance dredging (on a cubic-yard basis) had occurred between RMs 8 and 10, the main Portland Harbor depositional zone. The next largest percentages, approximately 2% and 1%, occurred in the downstream depositional zones at RMs 4 and 2, respectively. The remaining 2% of the maintenance dredging has been spread throughout the other portions of the Portland Harbor. This historical pattern in federal and Port dredging needs further supports the sediment transport regimes described previously.

3.0 CHEMICAL SOURCES

This section discusses potential current and historic sources of chemicals released to sediments in the ISA. It is intended to be a summary of currently recognized potential sources, not a definitive discussion of all possible sources of chemicals to the ISA. Ongoing sources to the ISA are likely a combination of the different types of sources discussed in this section. The magnitude of ongoing sources may vary spatially and temporally.

As required by the SOW, the LWG "will identify source areas that are contributing to contamination to the in-water portion of the Site. Although DEQ is primarily responsible for the control of upland contaminant sources to the Site, as part of the RI/FS, Respondents [the LWG] shall evaluate the distributions of sediment contaminants and, if appropriate (e.g., if the sediment data suggests the presence of an ongoing source), make recommendations to EPA and DEQ if the need for further investigation or control of sources is identified." Information provided in this section will be augmented by background source information to be provided in the updated CSM report.

3.1 CURRENT AND HISTORICAL INDUSTRIAL ACTIVITIES

Current or historical industrial activities and processes that may lead or may have led to either point or nonpoint releases to the ISA include petroleum storage and distribution; chemical (e.g., pesticide, herbicide, asphalt, paint, resins, acetylene) manufacturing and formulation; other manufacturing (e.g., laminated wood products, windows, refractory brick, silicon chips); oil gasification; pole treating; metals salvage and recycling (e.g., metals, batteries, oils, solvents, and automobiles); metals forging, fabrication and plating; storage and warehousing of various goods; marine fueling, construction and repair; electrical power generation; electrical substation operation and maintenance; railroad switching, fueling and maintenance; and shipping. In addition, Portland Harbor was the site of extensive shipbuilding and repair throughout World War II. Shipbuilding facilities were constructed beginning in 1941 (Osborn 1945).

Types of chemicals that may have been (or are being) released from facilities within the ISA include petroleum products, polycyclic aromatic hydrocarbons (PAHs), other semivolatile organic compounds such as phthalates and pentachlorophenol (PCP), polychlorinated biphenyls (PCBs), organic solvents, perchlorate, pesticides, herbicides, dioxins/furans and metals. Antifouling agents such as butyltins have also been released to the river in areas of commercial vessel traffic.

Table 3-1 includes a list of potential chemical sources within the ISA. The types of industries associated with specific chemical uses or chemical types are summarized in Table 3-2.

Facility-specific information on operations and potential chemical use or release is contained in Appendix E. The DEQ Environmental Cleanup Site Inventory (ECSI) database and nearly 40 Strategy Recommendations prepared by DEQ were reviewed to generate information on facility operations, possible chemicals of concern associated with the processes that would be anticipated, and pathways to the ISA. Results of this review for the facilities that received EPA General Notice Letters are provided in Appendix E, Table E-1. The information in Table E-1 is considered preliminary, and site-specific data may be available that more specifically addresses upland sources. Facility locations are shown on Map 1-2a-g

3.2 DISCHARGE OUTFALLS

Locations of outfalls compiled by the City of Portland Bureau of Environmental Services (1998) are shown in Map 3-1. General information on the types of dischargers to the LWR is summarized below. Drainage basins for City storm drains and combined sewer overflow (CSO) locations are also shown in Map 3-1. More detailed descriptions and evaluations of the city's outfalls, drainage basins, and facilities discharging to these outfalls are contained in a report compiled by CH2M Hill (2000b,c).

There are approximately 94 National Pollutant Discharge Elimination System (NPDES)-permitted discharges to the ISA[6]. Many of these permitted facilities discharge to the City's stormwater system. NPDES permits issued to facilities in the ISA are listed in Table 3-3; NPDES permits in the LWR outside of the ISA are listed in Table 3-4.

The types of permitted discharges in the ISA include industrial process wastewater, contact and non-contact cooling waters, treated water from cleanup projects, and stormwater from municipal sources, construction sites, and industrial facilities. Nearly all the ISA permittees are industrial dischargers classified as minor. There are no municipal sewage treatment plant discharges in the ISA.

Stormwater throughout the ISA drainage is collected and routed through stormwater collection systems and discharged at outfalls. There are approximately 234 non-City stormwater outfalls within the ISA (see Appendix E, Table E-2). There are about 13 City stormwater outfalls and four CSOs, with a high level of separation, within the ISA (Map 3-1). The City stormwater outfalls and CSOs generally drain large areas with multiple facilities within each drainage basin. CSOs only discharge sewage to the river during storm events when runoff combined with sewage flows exceeds the capacity of the wastewater collection and treatment system. The four combined basins in the ISA have been separated to prevent CSO discharges into the river except for storms exceeding a 3-year summer storm.

[6] 85 general and 9 individual NPDES permits

DEQ issues and enforces NPDES permits in Oregon. The permits set discharge limits or guidelines and specify the frequency and type of monitoring data that must be collected. Monitoring requirements are based on the size and type of facility and typically include basic parameters such as flow and pH. They may also include chemicals of concern at a given facility or bioassays. Chemical monitoring requirements for individual NPDES permittees in the ISA are summarized in Table 3-5. Examples of NPDES general monitoring requirements are listed in Table 3-6, although these requirements may be modified to address specific facility concerns. Individual permit limits may be based on either effluent concentrations or total loadings and may incorporate factors such as mixing zones or available technologies. Industrial stormwater discharges with general permits do not have flow or chemical limits. Instead, benchmark concentrations are established to assist permittees in evaluating the effectiveness of their stormwater management practices (Table 3-7).

Facilities are required to submit discharge monitoring data to DEQ. Currently, DEQ does not have an electronic database for discharge monitoring reports, although some facilities have begun submitting discharge monitoring reports electronically. In general, little or no quality assurance information is provided with the data submitted on the discharge monitoring report. Repeated violations of reporting requirements or exceedances of discharge limits may result in an enforcement action. Information on NPDES-related enforcement actions for permitted industrial and municipal dischargers in the ISA was compiled from 1995-2000 annual reports of the DEQ Office of Compliance and Enforcement (DEQ 2000a), and is summarized in Table 3-8.

The City entered into a memorandum of agreement (MOA) with DEQ for administration of NPDES General Permits 1200-Z, 1300-J, 1200-COLS, and future General Permits for Industrial Stormwater for those facilities located within the City of Portland that discharge to receiving waters and to the municipal stormwater system. As part of the MOA, the City reviews the facilities' stormwater pollution control plans, conducts independent stormwater sampling, and conducts inspections to ensure compliance with the plan and permit conditions.

3.2.1 Stormwater Runoff

Stormwater runoff to the ISA is discharged almost entirely via stormwater outfalls. However, there is some overland flow of water from properties immediately adjacent to the river. The volume of overland flow is small relative to the amount of stormwater discharged via outfalls.

Stormwater runoff can transport contaminated soils, wastes, or spills from areas throughout the drainage basin. Some potential sources of chemicals in runoff from the urban residential and commercial areas are pesticide and weed control products, leaking transformers, hydraulic and lubricating fluids, petroleum products, erosion, street dust, and deicing salts. Heavy metals, PAHs, and pesticides are some of the priority pollutant constituents found in urban runoff (Tetra Tech 1992; EPA 1983). For example, among the chemicals exceeding water quality criteria in stormwater runoff samples collected in Portland (at I-84 and at Harbor Way) in 1994 were cadmium, chromium, copper, lead, zinc, benzene, heptachlor, dieldrin, malathion, PCBs, and total dichloro-diphenyl-trichloroethane (DDT) (Anderson et al. 1996).

Numerous stormwater controls throughout the drainage basin were instituted over the last decade. The City of Portland and many facilities are now required to have NPDES permits for stormwater discharges, as well as stormwater management plans that incorporate best management practices (BMPs) to reduce the amount of pollutants in stormwater runoff. Monitoring is required, and although NPDES general stormwater permits do not generally set discharge limits, there are guidelines or benchmarks that are used to evaluate the effectiveness of stormwater controls. Common BMPs include removing industrial activities from exposure to rainfall and stormwater runoff, catch basin cleaning, street sweeping, and stormwater treatment (e.g., oil/water separators and other technologies).

NPDES stormwater monitoring data are submitted to DEQ. As with all NPDES monitoring data, information is compiled in individual facility files. The City of Portland Bureau of Environmental Services also maintains an electronic database of stormwater monitoring data for NPDES permits that it administers. Stormwater data for facilities within the City's outfall basins have been compiled for each City outfall (CH2M Hill 2000b,c).

3.2.2 Combined Sewer Overflows

The volume of CSO discharged from Portland's combined sewer system has been reduced as a result of stormwater controls and improvements to the combined and stormwater collection system (CH2M Hill et al. 1994). CSO overflows typically consist of 80% stormwater but also contain untreated sewage. Prior to 1994, the CSO system discharged an average of 4.8 billion gallons of untreated CSO (stormwater and sewage) to the Willamette River between RM 4 and 17 (CH2M Hill et al. 1994). The Cornerstone and Willamette CSO control projects helped Portland to achieve a 42% annual average CSO reduction in the Willamette system as of December 2001. By December 2011, the City's CSO program will achieve a 95% annual average reduction in the LWR.

Within the ISA, the CSOs experienced an average of 50 overflow events (up to a total of 112 days) per year in the early 1990s before the Cornerstone and Willamette CSO control projects in the ISA were implemented (City of Portland Bureau of Environmental Services 1998). Since 1997, CSO discharges in the ISA have been reduced to an average of three events per year, discharging about 1 million gallons annually. This represents an approximate 97% reduction of annual average CSO events within the ISA.

3.3 GROUNDWATER DISCHARGE

Extensive groundwater data have been collected from upland facilities throughout the ISA through site investigations conducted under Voluntary Cleanup Program agreements and consent or unilateral orders with DEQ. Approximately 83 sites have been identified on the DEQ ECSI database between RM 2 and 11. Of these sites, approximately 67 are known to have some groundwater quality data (Map 3-2).

There are abundant data from explorations at many sites that document groundwater conditions adjacent to the river, including hydrostratigraphy, groundwater gradients, and groundwater quality. The LWG is currently completing a review of available groundwater data to assess the locations and types of chemicals of interest (COIs) in groundwater adjacent to the ISA and to identify data gaps. For the purposes of this study, COIs are chemicals that have been detected in upland groundwater and have not been screened relative to potential impacts to the ISA using risk-based criteria. The existing data indicate that shallow and intermediate system groundwater under sites within the ISA generally discharges to the river. Direct evidence of discharge of groundwater containing COIs to the river is available at some sites along the ISA. Other sites have been identified as potential sources of COIs to the river via groundwater discharge; however, data are not available to verify whether or not contaminated groundwater is discharging at these locations.

Information on the groundwater physical system and existing groundwater quality data has been compiled from DEQ files and published literature, and will be submitted as part of the updated CSM report. The original documents obtained from DEQ on which the conclusions in this report were based will be provided to EPA for purposes of verifying the conclusions.

3.4 SPILLS

Spills are inadvertent, intermittent releases that occur directly to the waterway or adjacent upland areas. Spill records for the LWR were obtained from DEQ for the period 1995 to 2002 and are contained in Appendix E, Table E-3. Additional records of spills from the 1940s to present were requested from the U.S. Coast Guard and the National Response Center's (NRC) centralized federal database of oil and chemical spills. Detailed reports of spills from 1990 to present were provided, and summary information for spills from 1982 to 1989 was obtained from the NRC online database. These records are also contained in Appendix E.

Information on spill locations, particularly in the earliest reports, is often very general (e.g., RM). Spills reported in the LWR ranged from dropped bottles or sheens from unknown sources to fuel spills of over 500 gallons from vessels. Four of 20 spills reported to the U.S. Coast Guard between 1990 and 2003 involved volumes greater than 5 gallons. Of these four spills, one was greater than 1,000 gallons and was due to operator error while transferring fuel oil from a barge.

Additional historic spill information from transfer and handling practices or overwater activities is sometimes available in site-specific upland site assessments or remedial investigations. Spill information from these documents, when available, will be summarized in an updated CSM report.

Some of the types of activities commonly associated with spills are briefly described below:

- **Product Transfer and Handling.** The types of facilities on the LWR and products or chemicals associated with these industries are listed in Appendix E. Many facilities are now required to have spill prevention plans and have instituted practices to reduce spills.
- **Overwater Activities.** Overwater activities, including ship repair or vessel refueling, are potential sources of chemicals to sediments. Regulations and BMPs have reduced contributions from these activities in recent years. Currently, DEQ spill reports indicate that fuel spills during refueling are the most common type of spill from overwater activities, but small spills during transfer of other materials (e.g., paint) have also been reported.
- **Utility Crossings.** Pipelines carrying petroleum products have the potential to leak or break. There is one petroleum pipeline crossing the Willamette River within the ISA. It is located between the Willbridge bulk fuel terminal and south end of Triangle Park (approximately RM 7.7) (Maps 4-3b to 4-38b).
- **Vessels.** An average of 20 spills from vessels directly to the LWR are reported to the U.S. Coast Guard each year (NRC 2002). Nearly all involve diesel fuel, gasoline, hydraulic or lubricating oil, or waste oil. Vessels may also release bilge or ballast water to the river.

DEQ has developed spill rules that identify the emergency response actions, reporting requirements, and follow-up actions required in response to a spill of oil or hazardous materials. DEQ has also included spill records in its evaluation of potential contaminant sources to the LWR.

3.5 BANK EROSION

The majority of the ISA is industrialized with modified shoreline and nearshore areas. Wharves and piers extend into the channel, and bulkheads and riprap revetments armor much of the riverbank. The Portland Bureau of Planning mapped the banks of the Willamette River from the mouth to Ross Island (RM 15). They calculated that

50% of the banks were riprap, sea walls, other bank stabilization coverage, or structures. Remaining areas consisted of natural material (rock outcrops or native earth material with varying living or dead vegetation), river beach, or unclassified fill. Areas of unprotected shoreline where soils or fill containing chemicals may erode and be washed into deeper areas of the waterway are potential sources of chemicals to sediments. Some shoreline areas with known or suspected contaminated bank soils are located adjacent to ATOFINA, Crawford Street, GASCO, Linnton Plywood/Columbia River Sand and Gravel, and McCormick and Baxter facilities.

3.6 CHEMICAL LEACHING FROM COATED SURFACES

In-water structures, such as docks, pilings, dolphins and bulkheads, may be constructed of wood treated with creosote, chromated copper arsenate, or copper zinc arsenate. These preservatives are sources of PAHs, copper, chromium, arsenic, and zinc to sediments either through direct contact or via the water column. Sites with treated wood structures may have nearshore sediments potentially affected by chemical leaching; however, impacts are generally limited to the immediate area. For example, the spatial impact of creosote-treated wood, based on increases in sediment PAH, was less than 33 feet for small structures (i.e., less than 50 pilings); the spatial impact of leached metals to sediment was limited to within 10 feet (Poston 2001).

Leaching from vessel hull paints is a potential source of trace chemicals to sediments in areas with vessel activity (e.g., marinas, boatyards, shipyards) (Young et al. 1979; Crecilius et al. 1989). Antifouling pigments make up from 2% to 60% of the volume of a gallon of commercial marine paint (Burch 1987). Fouling marine organisms are killed as these pigments gradually leach out into the water. Antifouling paint and bottom primer components include cadmium, chromium, copper, lead, and zinc (Michelsen et al. 1996; Young et al. 1979). Historically, the most common antifoulants were organotins including tributyltin (TBT) and various mercury compounds. Use of mercury and TBT in antifouling paints has been restricted in the United States since 1972 and 1988, respectively, but ongoing sources include shipping traffic from countries without regulations and domestic vessels that are still allowed to use TBT paints.

3.7 ATMOSPHERIC DEPOSITION

Atmospheric deposition occurs both on the land and water surfaces in the ISA. Airborne chemicals deposited on land may be transported to the river in surface water runoff and therefore are associated with storm drain and stormwater runoff.

3.8 UPSTREAM SOURCES

Potential sources that may affect sediment quality in the ISA include all point and nonpoint discharges within the Willamette River basin. Chemicals in discharges and runoff from many diverse land uses in the basin are eventually deposited and mixed in the river by the time the river reaches the ISA.

3.8.1 Non-ISA Sources in the Lower Willamette River

Sources in the LWR, both downstream and upstream of the ISA, may contribute to chemical deposition in the ISA. Industrial and commercial facilities below RM 3.5 include petroleum storage and distribution, steel manufacturing, cement manufacturing, wood products storage and distribution, and marinas. The tidal influence of the Columbia River estuary causes seasonal flow reversals in the Willamette River near its mouth and within Multnomah Channel under certain river stage, river flow, and tidal conditions. These flow reversals could serve to transport sediment-bound chemicals from the downstream reach of the river into the ISA. Industrial and commercial activities immediately upstream from the ISA include aluminum storage, rail yard maintenance and operation, cement manufacturing, and marinas. Shoreline facilities upstream of the ISA that are listed in DEQ's ESCI database are listed in Appendix E, Table E-5, and locations are shown in Figure E-1). Permitted discharges are listed in Table 3-4. The City of Portland manages 34 CSOs upstream of the ISA. There are also numerous private and municipal outfalls upstream of the ISA.

3.8.2 Sources Above Willamette Falls (Upper Willamette River)

There are over 800 permitted discharges to the Willamette River upstream of Willamette Falls. The 28 major point source dischargers to the upper Willamette include over a dozen municipal sewage treatment plants and several pulp, paper, lumber, and fiberboard manufacturers. Hundreds of facilities also have general permits for discharge of non-contact cooling water and filter backwash, gravel mining activities, and tank cleaning. Over 300 permits for industrial stormwater discharge are held by a wide variety of facilities handling products such as paint, steel, metal plating, semiconductors, adhesives or food products, as well as landfills and transportation companies.

Nonpoint sources upstream of Willamette Falls include most of the agricultural and forested land in the Willamette River basin. Forested areas in the Willamette basin are located primarily in the mountains that border the western and eastern sides of the basin. The primary nonpoint source problem associated with forestry is accelerated sediment transport. Forestry practices also contribute runoff containing nutrients, fertilizers, and herbicides. Agricultural land in the Willamette basin is located predominantly in the Willamette Valley, and erosion from agricultural lands is the most commonly cited nonpoint source pollutant in the upper reaches of the

Willamette River basin (Tetra Tech and E&S 1993). Fertilizers, pesticides, and herbicides are agricultural chemical sources of nonpoint source pollution. USGS studies of pesticides in the Willamette basin reported the highest concentrations of organochlorine pesticides and PCBs at three, mostly agricultural, sites (Wentz et al. 1998). Urban areas in the Willamette basin, while a relatively small component of land use in the river above Portland (e.g., Eugene, Salem), may be sources of nonpoint pollutants associated with urban stormwater runoff (e.g., pesticides, PAHs, metals). The upstream reaches of the Willamette River basin also receive runoff from natural volcanic sources and past mining activities, which have resulted in a fish advisory for mercury throughout the entire main stem of the Willamette River.

DEQ's (1998) 303(d) list of impaired waters in Oregon includes the main stem and tributaries of the Willamette River above Willamette Falls. Most of the 303(d) listings for impaired water quality above Willamette Falls are for temperature and bacteria; other listings relate to nutrients, dissolved oxygen, and pH. There are some listings for toxic chemicals. Mercury, PCBs, aldrin, dieldrin, and DDT are listed for RMs 24.8 to 54.8. There are also smaller creeks in the middle and upper Willamette basins that are listed for arsenic, copper, lead, mercury, or zinc.

Based on the 303(d) list, DEQ is currently developing total maximum daily loads (TMDLs) for the 12 Willamette River subbasins (Table 3-9). Nine of these plans are due to be completed by 2003, and allocations have not yet been developed. Mercury is being addressed for the entire basin, and a dioxin TMDL was developed by EPA in 1991 for the Willamette and Columbia rivers.

4.0 SUMMARY OF PREVIOUS INVESTIGATIONS

As mentioned in Section 1, nearly 700 documents and data sets relating to the LWR from the confluence with the Columbia River (RM 0) to Willamette Falls (RM 26.5) were compiled during the preparation of this Work Plan. This section presents a brief summary of the environmental and human uses data. Additional ecological data are summarized in the Ecological Risk Assessment Approach (Appendix B).

The compilation of existing data relied on recent documents and data obtained from many sources, including LWG members, EPA, DEQ, Oregon Department of Fish and Wildlife, USGS, Corps, Oregon Natural Heritage Program, and county and university libraries. An extensive annotated list of data sources, along with data QA/QC information, is provided in Appendix F.

4.1 HISTORICAL DATA QUALITY REVIEW

Data quality reviews were performed for compiled historical sediment chemistry, water chemistry, tissue chemistry, bioassay, and macroinvertebrate data. The reviews were performed prior to entering the historical data into the project database. The purpose of this review was to fully evaluate each data set and categorize the quality of the data in the database, ensuring that these data were appropriate for use in the RI/FS. The two categories of data are as follows:

Category 1. Category 1 data are of known quality and are considered to be acceptable for use in decision making for the Site. There is sufficient information on these data sets to confidently verify that the data, along with associated data qualifiers, accurately represent chemical concentrations present at the time of sampling.

Category 2. Category 2 data are of generally unknown or suspect quality. The QA/QC information shows that data quality is poor or suspect, or essential QA/QC data (e.g., surrogate recoveries, matrix spike/matrix spike duplicates) are either incomplete or lacking.

The evaluation of data quality was conducted at the finest level of detail available for each data set. In many cases, complete QA/QC information was available and individual sample delivery groups could be evaluated. For other data sets, this level of detail was not possible because less backup information was available. The Category 1 and Category 2 designations are made at the finest level possible, which may result in some data from a given study being classified as Category 1 while other data are classified as Category 2. For example, metals data from a survey may be Category 1 while some of the pesticides data are Category 2. In many cases, data from one survey will contain both Category 1 and 2 data. Category 1 and 2 designations were entered into the project database for each sample and analyte.

Analyses upon which project decisions will be based will utilize Category 1 data. As examples, the ecological and human health risk assessments will use select Category 1 data in the risk calculations, and the definition of sediment management areas will rely on Category 1 sediment data. Only Category 1 data that have had an EPA-approved level of data validation, comparable to Washington State Department of Ecology's "QA2" evaluation, will be used for human health or ecological risk assessments. Usability of historical data is discussed in Section 4.6. Category 2 data will be used during project scoping. For example, Category 2 tissue data were used to help identify chemicals of interest, and Category 2 sediment data were used in the initial assessment of trends in chemical concentrations, which was useful for defining the site characterization sampling program.

4.1.1 Chemical Data Quality Reevaluation

During the review of the 2002 Round 1 Work Plan, the agencies emphasized the need to identify as many suitable chemical data points as possible for various components of the RI. In response, the LWG reevaluated historical Category 2 chemical data, and some data were reclassified as Category 1. The results of the reevaluation are presented in a technical memorandum entitled, Historical Chemistry Data Category Reclassification (SEA 2003). This section briefly describes the reevaluation process and its outcome.

The reevaluation focused on three distinct questions with regard to initial classification of the data:

1. Was all information necessary to assess data quality available initially?
2. Were chemical data quality criteria too restrictive?
3. Were criteria applied to data consistently?

The first step in the reevaluation process was to assess the outcome of the initial data quality review provided in Appendix F of the Round 1 Work Plan. It was noted that many surveys with Category 2 classification were lacking appropriate quality assurance/quality control (QA/QC) documentation necessary for data validation. It was also noted that in some cases the lack of chain-of-custody forms was responsible for Category 2 classification of otherwise high quality data. The second step in the process was to obtain source documents for all Category 2 data for the project library. Authors of those studies were contacted (whenever possible) and asked to obtain and transmit the necessary backup information. In the final step, the LWG performed the following tasks:

- Evaluate the adequacy of the chemical quality criteria
- Ensure that data quality criteria were consistently applied to all data, including those classified as Category 1

- Identify any QA/QC information that was either not initially available or that may have been originally overlooked
- Classify data based on newly acquired back-up documentation.

One of the original criteria for evaluation of data quality was revised. A data set was not rejected as Category 1 data based solely on the absence of chain-of-custody documentation as it was during the initial data quality evaluation. The revised process used to assess “traceability” is described in the next section. Additional QA/QC information was obtained for several studies, and chemical review criteria were consistently applied to all QA/QC results, both newly acquired and existing.

For tissue data, one study was upgraded to Category 1 for all chemical groups, and one study became a mixture of Category 1 and Category 2 data. Results of the reevaluation effort and reasons for Category 2 designation are provided in Table 4-1 and Appendix F.

4.1.2 Chemical Data Review Criteria

The chemical data review was conducted by analyte group (i.e., metals, semivolatile organic compounds, etc.) for each matrix type. As a result, a data set may contain all Category 1 data, all Category 2 data, or both categories 1 and 2 data. Data quality was assessed by evaluating the following four factors:

- **Traceability.** Based on the reevaluation of the chemical data, chain-of-custody is preferably documented and complete, and attached to the report or supporting documentation package. However, a data set is not rejected as Category 1 data based solely on the absence of chain-of-custody documentation. If a high-quality data set satisfies all criteria except chain-of-custody documentation, there may either be references to chain-of-custody forms in the text of a report or appendix or there may be other documentation consistent with state or federal guidelines that demonstrate investigators are typically compliant with industry standard field collection and documentation requirements and imply chain-of-custody forms were used. In that instance, an assumption is made that the investigator and contracted laboratories used appropriate sample tracking methods, and the data set is assessed as Category 1.
- **Comparability.** Analytical procedures or methods are identified and are accepted in the industry as "standard" or "universal."
- **Sample Integrity.** Sample holding times and conditions between collection and analysis meet established criteria,

which are generally identified by the EPA Puget Sound Estuary Program (PSEP 1986, 1997a,b,c) or other pertinent and published guidance.

- **Potential Measurement Bias.** Procedural and/or analytical method blanks are available to evaluate potential for introduction of positive bias in reported results, and bias is within acceptable limits. Lower reporting or quantitation levels may be limited by the presence of background or laboratory contamination. Potential measurement bias includes an evaluation of both accuracy and precision:

  - **Accuracy.** Matrix spikes (MS), laboratory control samples, (which may be spiked blanks or other pertinent reference materials), and/or organic surrogate compounds are available for review, and accuracy falls within an acceptable range. Recoveries fall within ranges typically established by major national monitoring programs, regional guidance, or other accepted "standards." Acceptable analyte recoveries tend to be in the range of 50% to 150%. Recoveries measured outside specified acceptance ranges generally result in the qualification of associated analytical results as estimates or unusable/rejected.

  - **Precision.** Replicate samples are generally available to evaluate analytical variability, and variability falls with an acceptable range. However, the lack of replicate data does not preclude Category 1 status as long as other laboratory quality control data to evaluate bias (e.g., blanks and accuracy quality control samples) are available for review to bolster the evaluation. When available, duplicate or triplicate analyses are normally performed at frequencies of 5% or once for every 20 samples analyzed (of the same matrix). Measurement of analytical variability for organic compounds is performed by analyses of MS and matrix spike duplicate (MSD) samples. (Occasionally, MS/MSD analyses are unable to provide desired measurements due to spike levels that were significantly less than native concentrations. This occurs mostly for highly contaminated solids where *in-situ* levels can be extreme compared to spiking levels.) Acceptable replicate analyses in most monitoring programs are less than or equal to 25% to 50% relative standard deviation or relative percent difference. Variability outside acceptance ranges results in the qualification of associated results as estimates.

Data sets that met the criteria above were assigned Category 1.

Sediment

Since March 2003, sediment chemistry results for four studies were added to the LWG's existing chemistry database:

- Lab Data for Phase 1 Data Evaluation and Phase 2 Work Planning for City of Portland Outfall 18 and Lab Data for City of Portland Outfall M-1 (City of Portland 2002)
- Environmental Site Assessment of GATX Terminals Corporation (KHM Environmental Management 1999)
- Forensic Geochemical Assessment of Nearshore Sediments, Remedial Investigation Work Plan, Atlantic Richfield/BP Terminal 22T (SECOR 2002)
- Revised 60-Inch Storm Sewer Interim Remedial Actions, Tosco Willbridge Terminal (KHM Environmental Management 2001).

Data quality reviews were performed for the four newly obtained studies plus 72 existing sediment studies, for a total of 76 sediment studies. Results of the evaluation are provided in Appendix F, Attachment F1, and are summarized in Table 4-1. Of the 76 data sets that were reviewed by analytical group, 36 were classified as Category 1 and 15 were classified as Category 2. Twenty-five surveys contained a mixture of Category 1 and Category 2 data.

Water

The water chemistry data from studies listed in Table 4-1 were evaluated for data quality. Results of the evaluation are provided in Appendix F, Attachment F2 and are summarized in Table 4-1. Data from STORET and LASAR were classified as Category 2. The remaining data sets were classified as Category 1. The lower rating for the monitoring data was primarily due to the lack of QA/QC documentation.

Data collected by DEQ monitoring programs are reviewed for quality assurance, and data in DEQ's laboratory analytical storage and retrieval (LASAR) database are provided with a quality ranking. All data from the LASAR database had been classified by DEQ as Level "A " or better, indicating that there is a Round 1 QAPP approved by DEQ, QA criteria are met, and that the data are suitable for evaluating compliance with water quality standards. The quality of data included in the EPA Data Storage and Retrieval System (STORET) database cannot be easily determined. However, data collected by USGS generally undergo QA/QC review. Data quality reviews of some of the USGS data compiled in this report are reported by Fuhrer et al. (1996) and Anderson et al. (1996). In general, these reports determined that data quality is adequate for use, with the following exceptions:

- Some USGS metals data collected prior to 1992 may be biased high due to contamination of the samples by the field sampling apparatus (Tetra Tech et al. 1993). Therefore, metals data collected prior to this date were not included in this compilation.

- Caution must also be used in comparing metals results as several different analytical methods were used. Therefore, in this plan the applicable method has been noted wherever appropriate.

Tissue

Data quality reviews were completed for eight surveys, and results are provided in Appendix F, Attachment F3, and are summarized in Table 4-1. All but two surveys were assigned to Category 2. The remaining two data sets were classified as Category 1 and a mixture of Category 1 and 2. In general, insufficient QA/QC documentation was available for the tissue chemistry data sets.

4.1.3 Biological Data Review Criteria

Bioassay and benthic community data quality were evaluated based on validation guidelines and performance criteria from the Puget Sound Estuary Program (PTI 1989).

Bioassay validation guidelines include checks of completeness, holding conditions, standard reporting methods, and QA/QC results for negative control, reference sediment, positive control (reference toxicant), and measured water quality parameters according to standard testing methods. Reference and control performance requirements were as follows:

- **Amphipod**. Control absolute mortality does not exceed 20%; reference absolute mortality does not exceed 30%.
- **Midge**. Control absolute mortality does not exceed 30%; reference absolute mortality does not exceed 35%.
- ***Daphnia sp.*** Control absolute mortality does not exceed 10%.
- ***Lumbriculus***. On Day 4, numbers of organisms should not be significantly reduced in test relative to control sediment. Organisms should burrow into sediment.

Reference sediment must have similar grain size as test stations.

For benthic community data sets, each study was reviewed for collection, laboratory, and sorting QA/QC methods. Data comparability among benthic data sets was also evaluated by comparing sampling methodology and sampler size, sample processing, and measured endpoints.

Bioassays

Data quality reviews were completed on seven types of bioassays (amphipod survival, midge survival and growth, oligochaete 28-day bioaccumulation (*Lumbriculus*), Microtox bacterial luminescence, *Daphnia* 48-hr and 96-hr mortality, and rainbow trout mortality for surface, subsurface, and sediment porewater spread over 18 surveys (Table 4-9 and Appendix F, Table 5). Four surveys assigned to Category 2, three surveys were assigned a mixture of Category 1 and Category 2 data, and the remaining bioassay data sets were assigned to Category 1.

Benthic Invertebrates

A literature search for information documenting the condition of the benthic invertebrate communities in the LWR found very little peer-reviewed data. Since 1993, only three studies, both inside and outside of the ISA, have focused on both the shallow and deep-water benthic communities in the Willamette River:

- Willamette River Basin Water Quality Study (Tetra Tech 1993, 1995; Tetra Tech and Taxon Aquatic Monitoring Co. 1994)
- Portland Shipyard Benthic Community Study (Dames & Moore 1998)
- Ecological Survey: Fall & Spring 2000 Ross Island Sand & Gravel Co. (Landau Associates 2000b).

A review of the methods used to obtain, process, and analyze the samples found that, with minor variations, internal QA/QC procedures (i.e., sample collection and processing; species sorting, identification, and enumeration; verification) were followed and that the data were suitable for the objectives of each study. Data from all three surveys (the only benthic data available in the LWR) were assigned Category 1 (see Appendix F, Table 6). However, a comparison of major benthic ecological indices among the three surveys is not possible because of differences in sampling gear, surface areas sampled, splitting methods, and sieve sizes.

4.2 CHEMICAL DISTRIBUTIONS IN SEDIMENT

The purpose of this section is to summarize sediment chemical concentrations in the LWR. Data presented here have been used in the Work Plan to assess data gaps. Depending on sediment stability, these concentrations may or may not be representative of current conditions or representative of sources that originated in the ISA. Historic data will be evaluated based on a weight-of-evidence approach as part of a data suitability analysis following the completion of Round 2 sampling. In this section, data from early investigations performed by the USGS and the Corps are summarized first (Section 4.2.1). Section 4.2.2 contains a discussion of the majority of compiled sediment chemical data from facility investigations that began after 1990.

4.2.1 Early Willamette River Sediment Quality Studies

This section summarizes sediment chemistry data collected prior to 1990. Some of the earliest publications with sediment chemistry data were USGS and Corps reports, primarily associated with dredged material characterizations. These early data sets were designated Category 2 primarily due to the lack of QA/QC documentation. Pre-1990 data are not mapped due to their age but are narratively described here.

Rickert et al. (1977) indicated that the sediment data collected prior to their study, which was performed in 1973, were “sparse” and that he and his colleagues were unable to assess the overall quality of sediment in the Willamette River given the lack of analytical data. Consequently, the purpose of their 1973 study was to provide baseline sediment metal concentrations for future comparisons.

Sediment was collected from 31 locations in the Willamette main stem, with 19 of the 31 samples collected from the LWR. The study limited the chemical analysis of sediments to trace metals, citing the lack of toxic organics listed in industrial discharge permits at the time. Aliquots of the sediment samples were separated to obtain fractions of fine silt and clay [i.e., <20 micrometers (µm)] that would be representative of local soils and worldwide averages of claystones and shales. In the LWR, arsenic ranged in concentration from 10 to 20 mg/kg (mean = 13); cadmium ranged from 0.5 to 2.5 mg/kg (mean = 1.2); chromium ranged from 50 to 80 mg/kg (mean = 57); copper ranged from 35 to 70 mg/kg (mean = 45); lead ranged from 25 to 90 mg/kg (mean = 43); mercury ranged from 0.03 to 0.34 mg/kg (mean = 0.14); silver ranged from 0.5 to 1.0 mg/kg (mean = 0.6); and zinc ranged from 260 to 1,295 mg/kg (mean = 419). All measurements were reported in dry weight.

In February 1977, the USGS and the Corps, Portland District, collected two surface sediment samples (top 8 inches) from a nearshore area slated for dredging at RM 9.2 (western shore) (McKenzie 1977). Samples were analyzed for grain size, conventional parameters (i.e., ammonia, total organic carbon, phosphorus, etc.), trace metals, phenol, PCBs, and several pesticides, including DDT and its breakdown products. Both samples were sandy silts with a mean value of 59% fines (silt plus clay). Trace metal concentrations were detected below the mean metal concentrations reported by Rickert et al. (1977). Among organics, PCBs, dichloro-diphenyl-dichloroethane (DDD), dichloro-diphenyl-dichloroethene (DDE), DDT, aldrin, dieldrin, chlordane, diazinon, lindane, and methoxychlor were detected. Total DDTs ranged in concentration from 11 to 15.6 µg/kg, dry weight (mean = 13.3), and PCBs ranged in concentration from 51 to 57 µg/kg, dry weight (mean = 54). The remaining detected pesticides and herbicides were detected at concentrations ranging from 1.0 to 10 µg/kg, dry weight.

As a follow-on to the February 1977 work, the USGS conducted an elutriate study on sediment samples collected from the same approximate location at RM 9.2 (Rinella and McKenzie 1977). Characterized sediments were slated for dredging. Two composite surface sediment samples were collected in May 1977 and prepared for both bulk sediment chemical analysis and elutriate-test filtrate testing. The elutriates were prepared by mixing dredged sediments collected from RM 9.2 with Willamette River and Columbia River water samples. The mixture was allowed to settle, and the supernatant was then decanted, centrifuged, and filtered. Both the bulk sediment samples and filtrates were tested for ammonia, trace metals, aldrin, chlordane, DDD, DDE, DDT, and dieldrin. The sediment sample contained approximately 60% silt and 12% clay. Arsenic, chromium, copper, lead, and zinc were detected at low levels in both samples. No sediment metal concentrations were detected above the average metal concentrations reported by Rickert et al. (1977). No pesticides or PCBs were detected in the elutriate test samples; however, PCBs, chlordane, DDD, DDE, DDT, and dieldrin were detected in the bulk sediment sample. Chlordane was detected at 15 µg/kg, total DDTs were detected at 26 µg/kg, dieldrin was detected at 0.5 µg/kg, and total PCBs were detected at 130 µg/kg.

In 1987, the Corps tabulated sediment chemical data from four surveys performed in the early 1980s by the Port of Portland, the Corps, EPA, and CH2M Hill (USACE 1987). These data were also summarized in Fuhrer (1989). Samples were collected from RMs 1 to 11.3, mostly from nearshore stations including slips and berths. Data for total organic carbon (TOC), grain-size distribution, several pesticides, and total PCBs were reported in the Corps’ 1987 report. Concentrations of dieldrin, endosulfan, endrin, heptachlor, lindane, methoxychlor, perthane, and toxaphene were either not detected or detected at low levels (0.1–5 µg/kg; maximum at RM 9.2). Detected concentrations of some or all of these chemicals were measured in samples collected from RMs 4.3, 4.5, 8.7, 9.2, 9.8, 10.1, 10.7, and 11.2. Detected concentrations of chlordane ranged from 2 to 7 µg/kg (maximum at RM 10.7) and were found at RMs 4.3, 4.5, 8.7, 9.2, 9.8, 10.1, 10.7, and 11.2. Concentrations of aldrin ranged from 2 to 7 µg/kg and were measured in sediments from RM 9.2. Total DDTs ranged in concentration from 1.6 to 3,413 µg/kg (maximum at RM 7.1) and were measured in sediments from RMs 1.2, 4.3, 4.5, 6.8, 7.1, 8.7, 9.2, 9.8, 10.1, 10.7, and 11.2. Total PCBs were detected in all samples but two and ranged in concentration from 14 to 550 µg/kg (maximum at RM 9.7, Berth 201).

In 1983, the USGS and Corps collected sediment and water samples from 10 locations in the navigation channel to determine concentrations of trace metals and organic compounds in elutriate-test filtrate and bulk sediment (Fuhrer et al. 1989). Samples were collected using both a ponar surface grab (top 10 cm) and a gravity core sampler (up to 1 meter), depending on the sample location. Samples were collected at RMs 4.3 and 4.5, mid-channel near Swan Island (RMs 8.3, 8.7, 9.2, 9.6), at RM 9.8, mid-channel at RM 10.1, and at RMs 10.7 and 11.3. Bulk metals concentrations were detected below mean metal concentrations reported by Rickert et al. (1977). Among organics, chlordane, DDD, and total PCBs were detected in all samples. Other organics, such as DDE, DDT, dieldrin, heptachlor, bis(2-ethylhexyl)phthalate (BEHP), and PAHs, were detected in specific samples. Total DDTs ranged in concentration from 1.6 to 19.2 µg/kg (maximum at RM 4.3), and total PCBs ranged in concentration from 14 to 170 µg/kg (maximum at RM 10.1).

Chlordane ranged in concentration from 1 to 10 µg/kg (maximum at RM 10.1). Bis(2-ethylhexyl)phthalate was detected in seven of 10 samples, ranging from 40 to 120 µg/kg (maximum at RM 9.8). The maximum total PAH concentration (3,190 µg/kg) was measured in sediment from RM 11.3.

In 1989, Fuhrer (1989) compiled and evaluated sediment chemical data collected between 1977 and 1983 in Portland Harbor, including the data reported above. Fuhrer (1989) concluded that the navigation channel sediments appeared to have lower chemical concentrations than sediments located in nearshore areas. That trend is supported by the data compiled for this Work Plan as well (see next section).

4.2.2 Sediment Chemistry Data Compiled by LWG

Available Category 1 and 2 historical sediment chemical data collected from 1990 to the present are summarized and mapped in this section. Category 1 and 2 designations by data set are presented in Table 4-1 and Appendix F, Attachment F1. As noted in Appendix F, sample density is the highest at facilities undergoing remedial investigations and dredged material characterizations. Maps 4-1 and 4-2 indicate the years samples were collected for surface and subsurface sediments, respectively. The majority of samples were collected either by EPA in 1997 during its Site Inspection (Weston 1998) or since 1990 by facility operators located between RM 4 and RM 9. In sediment investigations since 1990, chemical concentrations are most commonly reported for bulk sediment (i.e., the concentration in a sample of sediment). For some analytes, sediment porewater (i.e., water centrifuged from a sediment sample) is the preferred media. Data evaluations presented in this section are based on the data available. It’s important to note that a consistent suite of chemical constituents was not measured at each historical sediment sampling location.

Table 4-2 summarizes the sediment investigations performed in the LWR since 1990. Data from these investigations are currently available in the LWG’s database. Detailed descriptions of these historical sediment investigations are provided in Appendix F. This section provides a general description of sediment chemical concentrations measured in LWR sediments and porewater.

Chemical results for sediments that have subsequently been dredged are included in the LWG’s existing chemistry database and flagged as such. While dredged material sediment chemistry results do not provide an assessment of current conditions, the data provide information about potential historical sources and temporal changes. Dredged sediments received both Category 1 and 2 designations based solely on the assessment of laboratory QA/QC results as applied to all the data sets in the database. In this section, statistical summaries of the sediment chemistry exclude dredged sediment results to represent recent conditions. However, in maps the samples that have been dredged are marked and results are shown. In both the tables and maps, only data from 1990 to the present are summarized or mapped. Summary statistics for surface sediment samples collected in the LWR are presented in Table 4-3 (historical Category 1 and Category 2 data from 1990 to present, excluding dredged sediments). Summary statistics for all subsurface sediment samples in the LWR are presented in Table 4-4 (historical Category 1 and Category 2 data from 1990 to present, excluding dredged sediments). Surface samples are those that were exposed to the overlying water column to a maximum depth of 30 cm at the time of collection. Chemicals are sorted in order of descending detection frequency in the tables to identify which chemicals may have a relatively broad distribution in Portland Harbor.

With few exceptions, the same chemicals were detected at a frequency of 10% or greater in both surface and subsurface sediments, including metals, PAHs, diesel fuel, phthalates, total DDTs, total PCBs, butyltins, dioxins and furans, 4-methylphenol, dibenzofuran, xylenes, and acetone. Some noteworthy exceptions include the following. In the compiled surface sediment data, 2,4-D, 2,4-DB, chlorobenzene, di-n-octyl phthalate, heavy oil, and lube oil were detected in more than 10% of historical surface sediments (due to higher concentrations), but not in more than 10% of the historical subsurface samples. In subsurface samples, ethylbenzene, m,p-xylene, o-xylene, methylene chloride, methylethyl ketone, benzoic acid, 3- and 4-methylphenol (coelution), and alpha- and gamma-hexachlorocyclohexane were detected in more than 10% of the subsurface sediments, but not in more than 10% of the surface sediment samples. Tetrabutyltin and butyltin (as ion) were also detected in more than 10% of the subsurface porewater samples, but not in more than 10% of the surface porewater samples. It's important to note that the number of samples used to calculate frequency for each analyte group varies from 1 to 656 (surface) and from 1 to 390 (subsurface).

Detected concentrations of arsenic, cadmium, copper, lead, mercury, zinc, TBT (bulk measurements and in porewater), bis(2-ethylhexyl)phthalate, total high molecular weight PAH (HPAH), total low molecular weight PAH (LPAH), total PCBs, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD), total DDTs, dibenzofuran, 4-methylphenol, and xylene are mapped in Maps 4-3 through 4-38 to show the distributions of these frequently detected chemicals in the LWR. These chemicals were selected because they were detected in greater than 10% of the surface and subsurface samples in more than 10 analyzed samples, and they best represented major chemical groups (i.e., metals, pesticides/PCBs, SVOCs/PAHs, VOCs, butyltins, dioxins/furans).

Chemical distribution maps show data compiled to RM 16 because few data exist beyond this point. The chemical concentration ranges plotted on the maps vary between chemicals, and were determined by plotting frequency distribution curves (Category 1 and 2 detected concentrations) and selecting up to seven intervals that would represent the greatest number of samples for each chemical. Therefore, the maps summarize the relative concentration gradients for each target analyte for all existing surface and subsurface sediment data (detected values only). Sample locations of non-detected chemical concentrations are also shown. The same chemicals are mapped for subsurface sediment using the same concentration interval as those used for surface sediments. The maximum concentration measured in subsurface samples from each core location is shown. The distributions of metals (including organotins) and organic chemicals are discussed separately below. The discussion of chemistry data below is restricted to the location of *maximum* concentrations (i.e., red-colored symbols). A comprehensive discussion of chemical distributions in sediment within the LWR will be provided in the updated CSM. The selected chemical distribution maps presented in Maps 4-3 to 4-38 indicate that the highest detected chemical concentrations across a range of metals and organic compounds are not widespread in the LWR and are generally restricted to specific off-channel areas.

Metals and Tributyltin

The bulk sediment distributions of arsenic, cadmium, copper, lead, mercury, zinc, and TBT (bulk and in porewater) are plotted in Maps 4-3 through 4-20 (surface) and Maps 4-21 through 4-38 (subsurface). Overall, high metal and TBT concentrations are not widespread in the ISA and generally appear to be associated with specific facilities and operations occurring in physically sheltered areas off the main river channel. Relative to other concentrations detected in the ISA, maximum concentrations of arsenic were measured off MarCom (surface), U.S. Moorings (surface), Triangle Park (subsurface), Portland Shipyard (surface and subsurface), and in Swan Island Lagoon (surface). Maximum cadmium concentrations were measured in Terminal 4 (Slips 1 and 3, surface and subsurface), Willbridge Bulk Fuel Terminal (surface), Swan Island Lagoon (surface), and on the riverside of the Equilon dock. Maximum copper concentrations were measured in surface Marcom sediments, the Portland Shipyard (surface and subsurface), and in Swan Island Lagoon surface sediments. Maximum lead concentrations were measured off several facilities, including Oregon Steel Mills (surface), Terminal 4 Slip 1 (surface) and Slip 3 (surface and subsurface), MarCom (surface and subsurface), Hendron Tow Boat (surface), U.S. Moorings (subsurface), ATOFINA (surface), Portland Shipyard (surface and subsurface), Swan Island Lagoon (surface), between the City of Portland Outfall 18 and the inside of the Equilon dock, and the riverside of the Equilon dock. Maximum mercury concentrations were measured in surface and subsurface Portland Shipyard sediments. Maximum zinc concentrations occur in Terminal 4, Slip 3 surface and subsurface sediments, MarCom (surface), U.S. Moorings (surface), Portland Shipyard (surface and subsurface), Swan Island Lagoon (surface), and in the vicinity of Terminal 1 and Outfall 16 (surface and subsurface). The Portland Shipyard and the mouth of the adjoining Swan Island Lagoon have the highest porewater TBT levels in surface sediments. In addition to those facilities with porewater TBT, facilities with the highest bulk TBT in sediments included Schnitzer Steel’s International Slip (surface) and Triangle Park (subsurface).

In general, sediments in the main river channel do not show maximum metals concentrations relative to nearshore areas. Exceptions include navigation channel sediments at RM 7.7 (surface copper, subsurface bulk TBT) and RM 6.5 (surface TBT porewater).

Organic Compounds

The distributions of bis(2-ethylhexyl)phthalate, total HPAH, total LPAH, total PCBs, 2,3,7,8-TCDD, total DDTs, dibenzofuran, 4-methylphenol, diesel fuels, and xylene in sediments (detected concentrations only) are plotted in Maps 4-3 through 4-20 (surface) and Maps 4-21 through 4-38 (subsurface). As with the metals, relatively high levels of organic chemicals are generally restricted to nearshore facilities in the ISA. For example, the highest concentrations of total HPAH and/or LPAH have been measured in the vicinity of bulk fuel facilities (ARCO – surface and subsurface, Mobil Oil - surface, Kinder-Morgan Liquid Terminal – subsurface), PGE Harborton (subsurface), Linnton Plywood Association (subsurface), Transloader (subsurface), Hendron Tow Boat/Marine Finance (surface and subsurface), U.S. Moorings (surface and subsurface), Gasco facility (surface and subsurface extending into the channel), Wacker Siltronics (surface and subsurface), the McCormick & Baxter site (surface and subsurface) and Willamette Cove (surface and subsurface), the dock at ATOFINA (surface and subsurface),Goldendale Alumina (surface), offshore at UPRR, and at the Port of Portland’s Terminal 4 (surface and subsurface). Similarly, the highest concentrations of total DDTs have been measured just offshore of the ATOFINA Chemicals facility.

Maximum PCBs concentrations have been observed in the vicinity of Oregon Steel Mills (surface), Wacker Siltronics (surface), around the Portland Shipyard and in Swan Island Lagoon (surface and subsurface), between the City’s Outfall 18 and inside the Equilon dock, (surface), in the vicinity of Terminal 1 and the City’s Outfall 16 (surface and subsurface), off Goldendale and UPRR (surface), and Glacier Northwest (subsurface). Maximum concentrations of dioxins and furans were detected off McCormick & Baxter (surface). Maximum concentrations of bis(2-ethylhexyl)phthalate have been measured in Swan Island Lagoon(surface); at the adjacent Portland Shipyard (surface); at the Equilon facility (riverside - subsurface); at ATOFINA (subsurface); at Terminal 4, Slip 1 (surface); at the McCormick & Baxter site (surface); and in the vicinity of Terminal 1, both offshore and near the City’s Outfall 16 (surface).. Maximum dibenzofuran concentrations have been measured in sediments adjacent to the McCormick & Baxter site (surface),Willamette Cove (subsurface), Oregon Steel Mills (surface), Terminal 4 Slip 3 (surface), Mobil Oil (subsurface), Transloader (subsurface), Hendron Tow Boat (subsurface), Gasco (surface), Wacker Siltronics (surface and subsurface), U.S. Moorings (subsurface), and offshore of UPRR (surface). Maximum concentrations of 4-methylphenol were measured in sediments at Willbridge Fuel Terminals (surface), in Swan Island Lagoon (surface), and off the Gunderson facility (surface). Maximum concentrations of xylene have been detected at the Portland Shipyard (surface) and at Gasco (surface and subsurface). Maximum concentrations of diesel fuels occurred at Terminal 4 Slip 3. Like the metals, some organics are present in channel sediments, including dibenzofuran and PAHs at RM 6.3.

Trends in Chemical Concentrations by River Mile

Summary statistics for surface sediments and subsurface sediments, organized by river mile, are shown in Tables 4-5 and 4-6, respectively (historical Category 1 and Category 2 data since 1990, dredged sediment concentrations removed). Among analyte groups in the historical surface and subsurface data, PAHs were detected most frequently and were detected in greater than 10% of the samples collected in the LWR. Between RM 2 and RM 11, metals, PAHs, phthalates, total DDTs, total PCBs, dibenzofuran, 4-methyphenol, diesel fuels, and butyltins were detected in greater than 10% of the samples. However, some chemicals were unique to particular river mile segments in part because of the sample locations where these chemicals were analyzed. These chemicals are shown by river mile in Figure 4-1.

Average chemical concentrations for arsenic, cadmium, copper, lead, mercury, zinc, TBT (bulk measurements), bis(2-ethylhexyl)phthalate, total HPAH, total LPAH, total PCBs, total DDTs, 4-methylphenol, dibenzofuran, diesel fuel, xylenes, 2,3,7,8-TCDD, total organic carbon and percent fines (clay+silt) are shown graphically by river mile in Figure 4-2. Both surface and subsurface average sediment chemical concentrations are compared on each graph. It should be noted that the patterns that emerge from this display may result from the fact that there are more surface than subsurface samples. Some general observations are presented here for purposes of preliminary screening. Average subsurface chemical concentrations of mercury, bulk TBT, total DDTs, and diesel fuel are generally higher than corresponding average surface concentrations. This pattern is also true for total PCBs between RM 4 and RM 9. In contrast, average surface concentrations of bis(2-ethylhexyl)phthalate and 4-methylphenol are generally higher than corresponding average subsurface concentrations. The same is true for total HPAHs between RM 6 and RM 11; copper between RM 1 and RM 3, RM 4 and RM 7, and RM 8 and RM 11; and arsenic between RM 2 and RM 4, RM 5 and RM 7, and RM 8 and RM 11. For the few historical xylene and 2,3,7,8-TCDD measurements, average surface concentrations were greater than corresponding subsurface measurements. In addition, average surface and subsurface concentrations of TBT, total DDTs, total PCBs, total HPAHs, total LPAHs, and copper do not greatly differ from one another.

Patterns also emerge relative to river miles. In general, average surface chemical concentrations were generally higher than corresponding average subsurface concentrations between RM 2 and RM 3 and between RM 9 and RM 10. The opposite (greater subsurface than surface average concentrations) was true between RM 0 and RM 1 and between RM 3 and RM 4. Peaks in average concentrations also occur at certain river miles. Average surface concentrations of dibenzofuran (RM 7 to 8), zinc (RM 9 to 10), cadmium and lead (RM 2 to 3), and arsenic (RM 2 to 4, RM 5 to 6 peak well above corresponding average subsurface concentrations. For mercury, average subsurface concentrations peak well above average surface concentrations between RM 3 and RM 4. Peaks in metal concentrations generally occur between RM 2 and RM 6 and between RM 8 and 9. Peaks in DDT, 2,3,7,8-TCDD, and diesel fuel concentrations occur between RM 7 and RM 8. Xylene concentrations peak between RM 6 and RM 7. Total PCBs concentrations peak between RM 2 and RM 3 and again between RM 9 and RM 10. With the exception of bis(2-ethylhexyl)phthalate and 4-methylphenol, maximum chemical concentrations generally occur between RM 2 and RM 9, bracketing Portland's industrial area. The broad, bell-shaped curves of average total HPAH and total LPAH concentrations between RM 2 and RM 9 support this observation.

4.3 WATER QUALITY STUDIES

Water quality in the LWR reflects the diverse land uses and large size of the watershed. Chemicals in discharges and runoff from the variety of agricultural, urban, and forested land uses in the Willamette River basin are combined in the river by the time it reaches Portland. Water quality in the ISA may be additionally affected by point source discharges, surface water runoff, contaminated groundwater, and other sources discharging directly to this reach of the river (see Section 3).

The objective of this section is to review the water quality data most relevant to sediments and aquatic life in the ISA. For purposes of this Work Plan, data collected prior to 1990 are considered historic; data collected since 1990 represent current water quality conditions. For both recent and historic data, conventional parameters, including temperature, pH, dissolved oxygen, and nutrients, have the largest number of measurements. These parameters are the least costly to measure, provide a preliminary indication of water quality conditions, and use analytical methods that have been available for several decades (Fuhrer et al. 1996). However, they are not related to releases of hazardous substances and are therefore not of concern in the context of CERCLA. The chemicals measured frequently in bottom sediments (e.g., trace metals and organic compounds) have not been measured frequently in the water column, primarily due to the high cost of analysis.

This section reviews studies and summarizes data indicative of water quality in the river. Both general water quality (as indicated by routine monitoring conducted by government agencies) and site-specific water quality data are described. This section does not include water quality data collected as part of permitted discharge monitoring or stormwater data (see Section 3 for information on these sources and monitoring requirements).

4.3.1 Historical Water Quality

Conventional Parameters

Prior to 1990, dissolved oxygen (DO) was the conventional parameter of greatest concern in the Willamette River (Fuhrer et al. 1996; Rickert et al. 1977). Most aquatic organisms require adequate DO concentrations to survive, and anadromous cold-water fish are particularly sensitive to DO levels. Late summer, when river flow is lowest and air temperature highest, is historically the most critical period for DO levels in the LWR. Gleeson (1972) summarized DO data collected from 1929 to 1971. During the summer low-flow periods in the 1940s and 50s, the DO concentrations in Portland Harbor were below the state standard of 5 mg/L. A dramatic increase in DO was evident by the mid-1970s due to upgrading of wastewater discharges to secondary treatment and the release of additional water from the dams during the summer (Fuhrer et al. 1996).

The average temperature in the Willamette River has not changed significantly over time, particularly when compared to the seasonal changes and annual maximum and minimum temperatures (Gleeson 1972). Gleeson reviewed temperature data for 13 of the 41 years from 1929 through 1970. In all years reviewed, at least one station in the river had temperatures greater than 21ºC. As expected, peak temperatures in Portland Harbor corresponded to low water flow and highest air temperatures in July through September. Fuhrer et al. (1996) summarized monthly distributions of daily mean water temperatures in the Willamette River at Portland between 1976 and 1981. Minimum temperatures were consistently observed in January (0.1 - 9.0ºC), and maximum temperatures occurred in July and August (18 - 25.7ºC).

Bacterial concentrations have also been of concern. Methods for measuring and reporting bacterial concentrations have changed over time, and data are not directly comparable. However, Gleeson (1972) described historical trends in bacteria concentrations in the Willamette River. In general, bacterial concentrations during the 1920s and 1930s were elevated in the vicinity of municipalities and were roughly proportional to population, as all cities were discharging raw sewage to the river. By the 1940s, bacterial distribution patterns were the same but concentrations were increased, reflecting increased population. In the 1960s, bacterial concentrations were reported to be 5 to 100 times the limit considered safe for swimming. By the 1970s, bacterial concentrations began to decrease, reflecting improved sewage treatment. From 1962 to 1970, the average summer fecal coliform count dropped by a factor of 10 to 100 (Gleeson 1972).

Chemical Parameters

Tetra Tech et al. (1993) reviewed historical data on chemicals in the water column of the Willamette River and its major tributaries. Tetra Tech found that there are very little water column chemical data prior to 1990. DEQ routinely monitors major metals (e.g., aluminum, iron, manganese) but not chemicals that may be associated with the release of hazardous chemicals. Only one report in DEQ’s database contained chemical data collected prior to 1990. Water samples were collected at DEQ Station #402000 (Map 4-39) on August 30 and September 1, 1982, and were analyzed for over 100 volatile and semivolatile organics as well as PCBs and pesticides. Only four compounds were detected at levels that could be quantified: bis(2-ethylhexyl) phthalate, di-n-butyl-phthalate, di-n-octyl phthalate, and trichloroethylene.

4.3.2 Current General Water Quality

General (i.e., not associated with a specific facility) water quality data collected since 1990 in the LWR are summarized in this section. The main sources of data were DEQ and USGS monitoring programs. These data were collected as part of several programs, including DEQ's ambient monitoring program, USGS's National Water Quality Assessment program, and the Willamette River Basin Water Quality Study cooperative program between USGS and DEQ. These data were obtained through the EPA STORET and DEQ's LASAR database.

Nearly all data were collected at four DEQ or USGS monitoring stations in the LWR main stem (Table 4-7; Map 4-39). These stations had the greatest amount of data, most frequent sampling (including all months and flow conditions), and were determined overall to be most representative of general water quality in the lower river. Although there were data for other stations, they were sampled only on a single occasion or were representative of source characteristics rather than water quality in the river. Water quality data from the four DEQ and USGS stations most representative of general water quality in the river were obtained from the STORET and LASAR databases. These data are summarized in Table 4-8a-c. The most complete data are for conventional parameters. The ambient monitoring programs established by DEQ in the Willamette River also routinely monitor for metals, but not for organic pollutants. Recent organic data in the LWR main channel are limited to herbicide and pesticide analyses reported by USGS.

Conventional Parameters

Selected conventional water quality measurements since 1990 that are most relevant to sediment and aquatic life criteria and indicative of general water quality are summarized in Table 4-8a.[7] Temperature remains the water quality parameter of greatest concern in the LWR and is one of the reasons the LWR appears on the State of Oregon's 303(d) list under the Clean Water Act (DEQ 1998). Temperature measurements exceeding 20ºC have been reported in the late summer each year by DEQ. The State of Oregon currently plans to develop a TMDL for temperature in the LWR by 2003 (DEQ 2001a).

DEQ (2000d) reported that water quality in the main stem of the LWR remains poor, but showed significant improvement from 1990 to 1999 based on the Oregon Water Quality Index, a general water quality score incorporating 10 conventional water quality variables. Fecal coliform, elevated nutrients, and biological oxygen demand were cited as contributing factors to the low Oregon Water Quality Index score. DEQ is also developing TMDLs for bacteria, algae, and DO upstream of the LWR because of these persistent problems (DEQ 2001b).

[7] Types of measurements monitored but not included in Table 4-7 include color, conductivity, alkalinity, oxygen demand, and nutrients.

Inorganic Parameters

Although water column data for major metals are available for a limited number of locations, there are fewer trace metal measurements. In general, routine monitoring samples collected by DEQ are analyzed for major metals, including aluminum, iron, and manganese. A few samples collected by DEQ were analyzed for trace metals. However, a greater number of water samples collected by USGS from 1990 to 1999 (Station #14211720, LWR at Portland) were analyzed for over a dozen different dissolved trace metals. These data are also summarized in Table 4-8b. Detectable concentrations of copper, lead, nickel, selenium, and zinc were reported.

Recent studies have prompted the Oregon Department of Health Services (ODHS) to issue an advisory concerning elevated mercury concentrations in several fish species in the LWR. An ODHS (2001) news release states "Mercury in the fish is believed to come from natural volcanic and mineral sources in the headwaters of the river and possibly from a number of human-made sources along the river." Based on samples collected from 1969 through 1997, average mercury concentrations in smallmouth and largemouth bass and northern pikeminnow were 0.63 ppm. EPA's mercury criterion for human health is 0.30 ppm (ODHS 2001). This advisory has resulted in another listing for the LWR on the State's 303(d) list (DEQ 1998). The listing requires the DEQ to determine a TMDL for mercury in the LWR by 2003 (DEQ 2001b).

Organic Parameters

Recent data on water column concentrations of organic pollutants are also limited. No water column data for semivolatile or volatile organics collected during the past decade in the main channel of the LWR were found in the EPA or DEQ databases.

USGS analyzed water samples from the LWR at Portland (Station # 014211720) for approximately 100 organic compounds consisting almost entirely of herbicides and pesticides. Samples were collected between 1993 and 1998, and the results are summarized in Table 4-8c. Thirty compounds were detected. Atrazine, metolachlor, simazine, and deethyl atrazine were the most frequently detected pesticides. Of the pesticides and herbicides included as chemicals of interest in sediments in the LWR (SEA et al. 2002a), only dieldrin (total), DDE, and DDT were detected in water samples. Total PCBs were undetected in nine water samples collected by the USGS between 1994 and 1997.

EPA completed a TMDL assessment and allocation for dioxin in the Willamette River as part of a larger program for the Columbia River basin, and approved the dioxin TMDL in 1991. The TMDL develops waste load allocations for the chlorine bleaching pulp mills, including the Pope and Talbot mill located on the Willamette River at RM 148. The TMDL may be revised if other dioxin sources are identified. The target (i.e., loading capacity) dioxin allocation for the Willamette River (measured at Portland) is 0.54 mg/day.

4.3.3 Current Site-Specific Water Quality

Site-specific water quality data collected since 1990 in the LWR are summarized in this section. These data were collected as part of investigations pertaining to specific facilities, and therefore are not considered representative of overall water quality conditions in the ISA.

The Rhone-Poulenc survey (Woodward-Clyde Consultants 1995) analyzed water samples for 205 chemicals consisting of semivolatile and volatile organics, herbicides, pesticides, and dioxins/furans. Detected results included: 11 dioxins/furans, 5 pesticides, and 2 semivolatile organics (Table 4-8d). The McCormick & Baxter survey (PTI 1992) analyzed water samples for 18 PAHs only. Fluoranthene, fluorine, naphthalene, phenanthrene, and pyrene were detected (Table 4-8e).

A recent investigation at the McCormick & Baxter site (Ecology & Environment 2003) analyzed unfiltered and filtered water samples collected by EPA, DEQ, and Oregon State University (OSU) for PCP, metals (i.e., arsenic, chromium, copper, and zinc), and PAHs. Chromium, copper, zinc, and 15 PAHs were detected in the unfiltered samples, while arsenic, copper, fluoranthene, and pyrene were detected in filtered samples (Table 4-8f).

OSU also deployed passive sampling devices at their surface water grab stations at the McCormick & Baxter site. Semipermeable membrane devices (SPMDs) were used to monitor dissolved bioavailable organic constituents (PCP and PAHs), and diffusive gel thinfilms were used to assess labile metals (arsenic, chromium, copper, and zinc (OSU undated). Chromium, copper, acenaphthalene, anthracene, fluoranthene, fluorene, phenanthrene, and pyrene were detected (Table 4-8g).

4.4 ECOLOGICAL STUDIES

This section contains an overview of previous ecological studies conducted in the ISA. Details of these studies and how they will be used in the risk assessment process are provided in the problem formulation section of the Ecological Risk Assessment (ERA) Approach (Appendix B). The following is a description of the relevant sediment toxicity, benthic community, enzyme induction, histopathology, and tissue residue studies. Additional details, including results, maps, and descriptions of habitat types, fish, amphibians, aquatic plants, birds, and mammals, are found in Appendix B.

4.4.1 Sediment Toxicity

Sediment bioassays are laboratory tests in which benthic or epibenthic organisms are exposed to sediments. After a defined exposure period, organism survival or some other measure of an adverse biological effect is observed. Sediment toxicity tests are one tool to predict whether sediments have an adverse impact on resident species.

In 1998, the Corps, EPA, Washington State Department of Ecology, DEQ, and Washington State Department of Natural Resources prepared the Dredged Material Evaluation Framework for the Lower Columbia River Management Area (LCRMA) (USACE et al. 1998) to provide guidelines for dredged material sampling and testing. Since completion of the draft, dredging proponents with projects in the LWR have generally performed, when required, two tests to assess the suitability of dredged material for disposal at a freshwater site. These tests include the amphipod (*Hyalella azteca*) 10-day survival test and the midge (*Chironomus tentans*) 10-day survival and growth test.

In studies completed prior to the draft LCRMA guidelines, acute bioassays were performed using *H. azteca*, *Chironomus riparius*, *Daphnia magna* (water flea), and rainbow trout. These older studies also included elutriate testing of *D. magna* and trout. An elutriate test considers the effects of dissolved chemicals and chemicals associated with suspended particulates (after mixing has occurred) on water column organisms. A few studies used the Microtox test, which measures a decrease in bacterial luminescence caused by the presence of chemicals in sediments. Microtox tests are generally not currently used in regulatory programs.

All bioassay data were validated using “QA1” bioassay data validation guidelines (PTI 1989). QA1 is a term used by regulators in the Dredged Material Management Program (the umbrella regulatory agencies overseeing LCRMA) that allows an abbreviated level of review while providing confidence that the data have been adequately checked and approved for regulatory decision making. The QA1 level of review checks completeness, holding conditions, standard reporting methods, and QA/QC results for negative control, reference sediment, positive control (reference toxicant), and measured water quality parameters according to standard testing methods. Information provided in a standard laboratory report is generally adequate for performing a QA1 review.

For this data compilation, if the QA1 review led to questions concerning data quality, the data were categorized as Category 2 (unknown or of suspect quality). Otherwise, the data were placed in Category 1 (of known and acceptable quality). Category 2 data are those generally lacking supporting information to perform a QA1 level of review. One survey had two samples that were analyzed outside of recommended holding times, and those samples received Category 2 classification. Category 1 and Category 2 data designations are provided for each study listed in Table 4-9.

Table 4-10 lists existing bioassay studies for the LWR. Sample collection locations are shown in Map4-40. Bioassay results, including maps, specific to the ISA are listed in Appendix B, Section 3.5.

4.4.2 Benthic Community Structure

Benthic macroinvertebrates utilize various habitat types within a large river ecosystem. These habitats can generally be divided into soft and hard substrates, with soft substrates supporting an infaunal community and hard substrates an epibenthic community. These habitats are typically quite different in community structure and function.

The structure and function of macroinvertebrate communities within the Willamette River basin have been extensively investigated. However, few studies have focused on the LWR. Tetra Tech and Taxon Aquatic Monitoring Co. (1994) reported on the benthic macroinvertebrate community structure at six stations as part of the Willamette River Basin Water Quality Study. Dames & Moore (1998) sampled 16 stations in the Portland Harbor area, and Landau Associates (2000b) collected samples at 10 locations near Ross and Hardtack islands. Hjort et al. (1984) and Ward et al. (1988) conducted other limited investigations. In the summer and fall of 2002, the LWG conducted surveys of the epibenthic and infaunal macroinvertebrate communities found in the ISA as part of the Round 1 assessment of Portland Harbor. Detailed information about benthic communities in these and previous studies in the LWR is found in Appendix B.

4.4.3 Fish Community

Ellis Ecological Services (2000) reviewed the published and unpublished literature relating to the fish community in the LWR. Results from this review and more current research on fish use of the LWR are presented in Appendix B.

4.4.4 Wildlife and Aquatic Plants

Some literature exists that documents bird, mammal, amphibian, and aquatic plant species expected to occur in and around the LWR (Puchy and Marshall 1993; Csuti et al. 1997; Adolfson et al. 2000). In the summer of 2002, the LWG conducted a plant and amphibian survey of the LWR as part of the Round 1 assessment of Portland Harbor. Results from this survey and summaries of the above literature are presented in Appendix B.

4.4.5 Enzyme Induction Studies

Several enzyme induction studies of hepatic cytochrome P450-1A1 have been conducted in fish collected within the ISA and great blue heron embryos collected outside the ISA. These studies are summarized below. Cytochrome P450 enzymes are important in detoxifying exogenous compounds in most fish, birds, and mammals. Induction of cytochrome P450-1A1, which catalyzes ethoxyresorufin O-deethylase (EROD) and aryl hydrocarbon (benzo[a]pyrene) hydrolase activity, has been correlated with toxic potency of contaminants. Per the AOC/SOW, the risk assessment will only consider effect endpoints associated with growth, reproduction, and mortality. The following studies have been evaluated per requirements of the AOC/SOW. In the ecological risk assessment, these studies will be evaluated to determine if any of the enzyme induction endpoints are appropriate for inclusion in the effects assessment.

Curtis et al. (1993) investigated the sensitivity of cytochrome P450-1A1 induction in fish as a biomarker for distribution of 2,3,7,8-TCDD and 2,3,7,8-tetrachlorodibenzofuran (TCDF) in the Willamette River. This study examined the relationships between TCDD or TCDF and induction of microsomal EROD and total cytochrome P450-1A1 content in muscle tissue from the common carp and the northern pikeminnow. Thomas and Anthony (1997) used both EROD and the H4IIE assays to detect induction of cytochrome P450-dependent enzymes in great blue heron embryos exposed to 2,3,7,8-TCDD and structurally similar compounds at Ross Island (a site upstream of the ISA). The EROD assay determined the impact of chemicals in the egg on a developing embryo, and the H4IIE assay determined the potency of the egg contents to induce enzymatic activity in rat hepatoma cells.

4.4.6 Histopathology

This section summarizes available data in the LWR related to animal histology or histopathology. Histopathology refers to microscopic changes in diseased animal tissues as a result of exposure to chemicals. In the ERA, these studies will be evaluated to determine if any of the histopathological endpoints are appropriate for inclusion in the effects assessment.

Fish Histopathology

DEQ (1994) and Tetra Tech (1993) collected northern pikeminnow and largescale suckers from various sites along the Willamette River. In the Portland Harbor, samples were collected at RM 1 and within the ISA at RM 6.5 (Tetra Tech 1993) and at RM 7 (DEQ 1994). Both studies qualitatively evaluated external and internal features and measured blood parameters using assessment methodology developed for salmonids.

Curtis et al. (1993) conducted a microscopic examination of common carp, cutthroat trout, and northern pikeminnow liver, gills, kidneys, spleen, stomach, and gonads. One station was sampled in the ISA at RM 7.

As part of the McCormick & Baxter RI (PTI 1992), Pastorok et al. (1994) examined 249 largescale sucker livers, including those collected from two stations near RM 7 and one station near RM 6.

Two studies have addressed skeletal deformities in fish collected in the LWR. From 1992 to 1994, Tetra Tech (1993, 1995) examined skeletal abnormalities in juvenile northern pikeminnow collected at RM 3. The incidence of skeletal abnormalities at

RM 3 was consistently low and within a range of 2 to 5% reported for unstressed natural fish populations and laboratory stocks (Tetra Tech 1995). In 1998, EVS Environmental Consultants (2000) determined the incidence of skeletal abnormalities to be 19.7% in 71 chiselmouth collected upstream of the ISA at RM 15.

Avian and Mammalian Histopathology

In general, very few studies have been conducted that address histopathological changes in birds and mammals occurring in the LWR area. One study examined a great blue heron rookery in the LWR upstream of the ISA. Thomas and Anthony (1997) compared eggshell thinning at the Ross Island heronry with that at Fisher and Bachelor islands in the lower Columbia River. Henny et al. (1996) conducted a study in the Portland-Vancouver area of the Columbia River that examined relationships between reproductive tract disorders in river otters and chemical concentrations measured in river otter livers.

4.4.7 Tissue Residue Studies

Very few studies of chemical residues in fish and benthic invertebrates have been undertaken in the LWR. The following discussion summarizes data compiled from various toxicological studies of chemical residues in fish and benthic invertebrates of the Willamette basin, with particular emphasis on studies or portions of studies that have occurred in the LWR. The tissue residue data will be used to assess risks associated with the consumption of fish and benthic invertebrates by birds and mammals, as well as risks to fish species resulting from their chemical exposure within the ISA. Tissue chemistry results are summarized in Table 4-11. When possible, concentration data were converted to wet weight.

Fish and Benthic Invertebrate Tissue Residue Studies

Tissue residue studies were evaluated for data quality in the same manner as the sediment chemistry data (see Appendix F). Of the seven studies identified, none of the data were considered Category 1 due largely to the lack of supporting analytical QA/QC information. However, these studies are briefly summarized below, as they remain valuable in the initial understanding of tissue residue levels in fish and invertebrates from the LWR and in formulating future work efforts. Tables B-3a and B-3b in Appendix B provide the complete set of fish tissue data collected within the ISA.

PTI (1992) collected largescale sucker and crayfish from five locations near the McCormick & Baxter site (at RM 7). PAHs and metals were detected in both the sucker muscle tissue and the whole-body crayfish tissue.

Black crappie, common carp, and smallmouth bass were collected by *The Oregonian* (2000). Organochlorine pesticides (including DDT), PCBs, and mercury were detected in whole-body tissues collected in the Harborton Forest and wetlands, Terminal 4, and RM 5 to 6.

Mercury was detected in muscle fillets of common carp, largemouth bass, northern pikeminnow, largescale sucker, and smallmouth bass collected by DEQ (2000b). No other chemicals were analyzed in this study.

EPA (1992) analyzed fillet and whole-body tissues of common carp and northern pikeminnow collected in the railroad bridge area (at RM 7). Six carp fillets and six northern pikeminnow whole-body samples were analyzed for dioxins and furans. In addition, three carp fillets and three northern pikeminnow whole-body samples were analyzed for pesticides, PCBs, and DDTs.

Finally, one common carp whole-body tissue sample was collected from RM 9 and analyzed for dioxins and furans by Bonn (1998).

Additional Bioaccumulation Studies

In addition to the data cited above and in Appendix F and Table 4-11, other sources of applicable bioaccumulation data have been identified. In November 1999, the Corps (1999) collected five sediment samples from the LWR at locations within and outside the ISA. Sediment samples were submitted for 28-day bioaccumulation testing to evaluate uptake of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT in *Lumbriculus variegatus*, a freshwater oligochaete. As shown in Table 4-12, 4,4'-DDD and 4,4'-DDE were detected in the oligochaete.

Thomas and Anthony (1997) measured concentrations of pesticides, PCBs, dioxins, and furans in fish tissue and heron eggs at Ross Island to evaluate chemical biomagnification from prey items of the great blue heron.

4.5 SUMMARY OF HUMAN USES

This section describes the current understanding of the physical and biological setting of the ISA as it pertains to potential human uses, including specialized groups that may use the river for various activities. Most of the demographic information relating to the ISA is based on historical background and documented human uses. This information is used to determine potential receptor populations and to develop the general CSM.

Portland Harbor and the Willamette River have served as a major industrial water corridor for more than a century. Industrial use of the ISA and adjacent areas has been extensive. The majority of the ISA is currently zoned for industrial land use and is designated as an "Industrial Sanctuary" on the Portland Comprehensive Plan Map (City of Portland 2001a). The Portland industrial sanctuary policy is designed to encourage the growth of industrial activities in the city by preserving some industrial land primarily for manufacturing purposes. The Guild's Lake Industrial Sanctuary Plan (GLISP) is intended to preserve and enhance industrial land in the area generally bounded by Vaughn Street on the south, the St. Johns Bridge on the north, Highway 30 on the west, and the Willamette River on the east (City of Portland 2001a). Over many decades, public and private investments in infrastructure, such as marine, rail and highway facilities as well as investments in industrial physical plants, have made the Guild's Lake Industrial Sanctuary one of the premier heavy industrial districts in the Pacific Northwest. The purpose of the GLISP is to maintain and protect this area as a dedicated place for heavy and general industrial uses. The plan's objectives were adopted as part of Portland's Comprehensive Plan to ensure preservation of this land use over the next 20 years.

Much of the shoreline in the ISA includes steeply sloped banks covered with riprap or constructed bulkheads, with human-made structures such as piers and wharves over the water in various locations. A comprehensive update of Portland's Willamette Greenway Plan and related land use policies and zoning is underway, addressing all of the Willamette riverfront in Portland (City of Portland 2001b). The plan update may affect land use practices (e.g., stormwater management) in Portland Harbor, but it will not affect the "Industrial Sanctuary" designation.

Worker activities that may include contact with sediments and surface water at industrial and commercial facilities in the ISA are limited in the shoreline areas due to the sparse beach areas and high docks associated with most of the facilities.

In addition, the LWR provides many natural areas and recreational opportunities, both within the river itself and along the riverbanks. Within the ISA, Cathedral Park, located under the St. Johns Bridge, includes a sandy beach area and public boat ramp and is used for water skiing, occasional swimming, and waterfront recreation. Recreational beach use also may occur within Willamette Cove, which is a riverfront natural area, and in Swan Island Lagoon. Swan Island Lagoon includes a public boat ramp. Additional LWR recreational beach areas exist on Sauvie Island and in Kelly Point Park, both of which are outside of the ISA. Potential recreational beach use areas in the ISA are shown in Map 4-41a-c.

The St. Johns Town Center is a mixed-use district that extends to the waterfront on the east side of the Willamette River at the St. Johns Bridge. Proposals emerging in the recent St. Johns-Lombard Plan project and neighborhood-generated Linnton Neighborhood Plan include redevelopment for areas near the Willamette River. These areas are potential examples of the "vibrant waterfront districts and neighborhoods" theme in the River Renaissance Vision developed by the City of Portland.

The exact extent to which commercial fishing occurs within the ISA is currently not known. No reports of commercial fisheries for anadromous salmonids on the Willamette River have been found. A limited commercial crayfish fishery exists in the Lower Willamette River. However, non-commercial fishing is conducted throughout the LWR basin and within the ISA, both by boaters and from locations along the banks. A news story by *The Oregonian* and the limited interviews by ATSDR suggest that the groups most likely to be catching and eating fish from the LWR include immigrants from Eastern Europe and Asia, African-Americans, and

Hispanics. These same sources also suggest that the most consumed species are carp, bullhead catfish, crappie and small-mouth bass (ATSDR 2002). Other sources (CRITFC 1994) suggest that Native Americans fish in the Willamette River. The LWR provides a ceremonial and subsistence fishery for Pacific lamprey and spring chinook salmon for Native American Tribes. Many areas in the LWR are also important currently for cultural and spiritual uses by local Native Americans.

Transients have been observed along the LWR, including some locations within the ISA. The observation of tents and makeshift dwellings affirms that transients were living along some riverbank areas. Transients are expected to continue to utilize this area in the future.

4.6 USABILITY OF HISTORICAL DATA

A substantial amount of historical data for the LWR have been compiled and presented in earlier sections of this Work Plan. The usability of these data for the risk assessment and FS needs to be ascertained as the distribution of acceptable historical data will affect the development of RI sampling programs. The principal issues related to the usability of historical data include data quality, sediment stability, and the intended use of the data. All of these factors must be acceptable for data to be considered usable.

The quality of the existing data has been evaluated (Section 4.1 and Appendix F) and data have been categorized as Category 1 (data are of known quality and are considered to be acceptable for use in decision making for the Site) or Category 2 (data are of generally unknown or suspect quality). This evaluation focused on individual analyte groups within each survey when possible, and so any given survey may contain all Category 1 data, all Category 2 data, or a combination of Category 1 and 2 data. Overall, the existing data collected within the ISA that qualify as Category 1 data are principally associated with sediment chemistry and toxicity studies using benthic organisms. Category 1 sediment chemistry data will be evaluated for use in determining the distribution of chemicals in the ISA, understanding sources, and identifying remediation areas. As discussed further in this section, it is believed that much of this data will be usable for these purposes; however, those Category 1 data determined to be critical to human health or ecological risk assessments require an EPA-approved level of data validation, comparable to Washington State Department of Ecology’s “QA2” evaluation. Currently, there are less than 10 sediment investigations meeting these criteria, rendering most existing Portland Harbor sediment chemistry data unusable for risk assessment. In addition, almost all other types of historical environmental data collected have been determined to be Category 2 data and therefore may be of limited use in the RI/FS, subsequent to project scoping.

Table 4-13 presents the number of post-1990 Category 1 sediment samples in Portland Harbor by river mile for each analyte class. As the table demonstrates, there are considerable existing Category 1 sediment analysis data available for use in the RI/FS, such as the development of sediment management areas. The number of samples analyzed varied for each analyte class: excluding conventionals, up to 507 surface sediment samples and 337 subsurface sediment samples were each analyzed for a given analyte class. PAHs were the most frequently reported analyte class for both surface and subsurface sediment samples. Herbicides and dioxins and furans were the least frequently reported analyte class for both surface and subsurface sediment samples.

The evaluation of sediment stability will continue to determine whether existing chemical concentrations continue to represent conditions at the locations where sampling occurred. Results of the LWG's STA®, SPI, and bathymetry studies (Section 2) suggest that the majority of the ISA has been a relatively stable and depositional physical sediment environment over the last decade. Nearshore areas (i.e., sediment at water depths shallower than –20 feet CRD) are predominantly stable with episodic deposition, apart from localized disturbances by non-flow-related physical processes (e.g., wind-generated waves) and/or anthropogenic disturbances (e.g., prop wash, nearshore construction, dredging) (SEA 2002f). Channel areas from RMs 1.1 to 5.1 and RMs 7 to 9.7 are also predominantly depositional. A sediment transport/non-depositional zone occurs within the channel from RMs 5.1 to 7. The vast majority of Category 1 sediment samples were collected from nearshore areas, while very few (approximately 10) samples were collected from the channel from RMs 5.1 to 7. The evaluation of sediment stability will continue during the RI with the following types of data collections and evaluations:

- A third bathymetric survey has been completed and was provided to EPA in October 2003. An evaluation of the bathymetric changes using this new data set was provided to EPA in the Round 2 sediment and benthic toxicity testing FSP.
- A fourth bathymetry survey was completed in March 2004 following a relatively high flow event (approximately 140,000 cfs). These data will be available in the spring of 2004 to support the modeling effort (next bullet).
- Hydrodynamic and sediment transport modeling will provide important insights into the relative stability of sediment throughout Portland Harbor, including areas that may be expected to either erode or accrete under hydrodynamic conditions that have occurred since 1990 (the date of the earliest historical data used in this project). The technical approach memo for the modeling task is currently under EPA review.
- The Round 2 sediment and benthic toxicity testing FSP includes recommendations for sampling areas that have previously been sampled to assess the level of change in chemical concentrations. Chemical

concentration changes are anticipated due to analytical variability and environmental patchiness. However, if the pattern of chemical concentrations in a region of the ISA changes then the usability of the historic data in that area will need to be assessed.

- Radioisotope dating of sediment cores will likely occur in Round 2 when subsurface cores are collected. These data will provide information on the history of sediment deposition at the sample location.

The LWR is and will continue to be a dynamic river system, and it is inappropriate to assume that one data set may best represent conditions in the river. In fact, a combination of data sets that represent different points in time may best represent the range of conditions that could reasonably be expected to occur in the future. The analysis of sediment stability will help to define the areas that have the highest probability of changing over time.

The final consideration for determining data usability is evaluating the intended use of the data. For example, the historic database contains some samples with undetected concentrations of PCBs at high detection limits. From an analytical perspective, these data are Category 1 and acceptable for use. From a sampling design perspective, these data are not useful because of the uncertainty associated with concentrations below the high detection limits and additional sampling and analysis may be necessary. From a risk assessment perspective, these data are also likely not useful because of the uncertainty associated with concentrations below the high detection limits and therefore the risk associated with these concentrations cannot be defined. As another example, chemical data from areas that have been dredged are useful for assessing potential historic sources but are not useful for assessing current risk.

The majority of information for this assessment will be available following Round 2. This information includes evaluation of the third bathymetric survey, additional surface sediment chemistry, and results of hydrodynamic and sediment transport modeling. All existing Category 1 chemistry data to be used for any purpose during the RI/FS must first be evaluated to determine its suitability for use. Factors to be considered include, but are not limited to:

- The use of appropriate detection limits,
- Sample compositing techniques,
- Analytical methods,
- Age of data,
- Sample depth, and
- Whether the sample is located in an area of scour or deposition.

The comprehensive site characterization summary and data gaps analysis report that is prepared following Round 2 will contain an assessment of data usability based on available information. The RI report, prepared following Round 3, will contain an updated discussion of data usability.

5.0 PRELIMINARY CONCEPTUAL SITE MODEL

This section describes the preliminary conceptual site model (CSM) for the ISA that is based on the current understanding of the physical and biological characteristics of the LWR. The CSM is a written description and graphical presentation of the relationships between chemicals released into the environment and the receptors (human or ecological) that may be exposed. The primary components of a CSM are source(s), release mechanism(s), transport pathway(s), affected exposure media, exposure routes, and receptors. For an adverse effect to occur, each one of the above components must be present. The following sections present a model of the physical system (Section 5.1), including a summary of potential sources and potential release mechanisms, and a summary of the potential transport and exposure pathways to ecological (Section 5.2) and human receptors (Section 5.3). Additional details of the ecological and human health CSMs are found in Appendices B (ERA Approach) and C (HHRA Approach).

The preliminary CSM presented herein will be updated as a stand-alone report (updated CSM). The updated CSM will provide a detailed inventory of sources and pathways for chemicals to impact sediment, the groundwater/surface water Transition Zone, and surface water in the river. A revised CSM will be based on results of further review of upland groundwater and other source and pathway information and will be submitted to EPA in accordance with the project schedule (Section 9.5). The CSM will be further updated as information gathered at the Site triggers revisions or refinements of the CSM.

5.1 PHYSICAL CONCEPTUAL SITE MODEL

Figure 5-1 is the preliminary physical CSM that summarizes potential sources, release mechanisms, transport media, and exposure media in the ISA. Site history and site conditions that support the physical CSM can be found in Section 2 of this Work Plan. Each of these categories is discussed in the sections that follow.

5.1.1 Sources

Potential sources of chemicals to the ISA are detailed in Section 3 of this Work Plan. In total, sources that may affect or have historically affected sediment and water quality in the ISA include all point and nonpoint discharges or releases at the ISA and upstream of the ISA. Potential sources in the ISA include the full range of current and historical industrial and urban activities (see Table 3-1), including overwater activities and discharges from public and private outfalls. Potential sources located upstream and, to a much lesser extent, downstream (due to seasonal, tidally induced flow reversals in the river), include industrial, urban, agricultural, and silvicultural activities that may release chemicals to the river system that eventually are transported to the ISA.

5.1.2 Release Mechanisms

There are several potential release mechanisms by which chemicals may have reached or can reach the surface waters and sediments in the ISA (Figure 5-1). Point source releases include historic and on-going direct industrial discharges, outfalls associated with CSOs, and piped stormwater discharges. Nonpoint source releases include overland stormwater runoff from industrial, commercial, and residential areas adjacent to the ISA, as well as watershed-wide upstream source releases including runoff from agricultural and silvicultural areas in the Willamette basin. Other potential release mechanisms include spills (both land-based and in-water), wind- and precipitation-induced erosion and transport of soils, infiltration of liquids, leaching of buried wastes, chemical leaching from structures and vessels (discussed in Section 3.6), and chemical or biochemical processes that mobilize chemicals such that they migrate from soils and sediments to surface water and groundwater.

Erosion and Transport

Exposed surface soils in upland areas that drain to the river and are exposed along riverbanks can be eroded and transported to the river by runoff. Chemicals present in soils or adhering to soil particles may thereby be translocated to the river. The amount of potentially impacted soils that is exposed in the Portland Harbor area is expected to be relatively small, as the vast majority of the industrial area along the river is paved or covered by buildings. Therefore, erosion of impacted upland soils and transport to the river is not anticipated to be a major ongoing release mechanism at the ISA, although it may have been more significant in the past. Approximately half of the riverbank in the ISA is covered with various engineered materials. Erosion of exposed riverbank soils by episodic high river flows is likely to be a more significant mechanism than erosion of upland soil.

Chemicals in dust, soil, debris, and liquids present on impervious surfaces, such as roadways, parking lots, and building roofs, can be transported to the river by stormwater draining to outfalls within Portland Harbor. These materials collect on the impervious surfaces over time; therefore, it is anticipated that stormwater runoff events occurring after extended dry periods (e.g., early wet-season "first flush" storms) would transport relatively greater amounts of chemicals to the river than would individual, frequently spaced runoff events (e.g., mid-winter storms).

Wind erosion and transportation of chemicals in soil and dust is anticipated to be a relatively minor mechanism for releasing chemicals to the river. As mentioned above, there is little exposed soil in the industrial area along the river. Also, in comparison to other mechanisms, wind is not very effective at transporting significant mass from potential source areas to the river.

Infiltration, Leaching, Dissolution, and Adsorption

Chemicals may be present in soil as solids, dissolved constituents, or non-aqueous phase liquids (NAPLs), including light non-aqueous phase liquids (LNAPLs) and dense non-aqueous phase liquids (DNAPLs). Liquids released to soil may infiltrate and percolate through the soil column to groundwater as diagrammed in Figure 5-2a.

LNAPLs released to soil will migrate vertically downward to low-permeability zones or to the water table where unrestricted. Thus, the vertical distribution of LNAPLs in the unsaturated zone is controlled by the depth of the water table, as well as by the vertical permeability and sorptive capacity of the sediments. Lateral migration of a LNAPL is controlled by (1) the gradient of the groundwater surface, (2) the presence of permeable layers within the uppermost-saturated unit, which is usually fill or undifferentiated fine-grained sediments, (3) the volume and rate of the release, (4) the presence or absence of human-made or natural preferential pathways, and (5) the physical characteristics of the LNAPL. At the groundwater surface, LNAPLs typically produce a dissolved plume for chemicals, such as aromatic volatile organic compounds (VOCs) [e.g., benzene, toluene, ethylbenzene, xylenes (BTEX)] and other chemicals that may extend some distance downgradient from the LNAPL itself. Attenuation processes, such as biodegradation, adsorption to soil particles, and various geochemical processes, affect the migration of dissolved organic plumes. The degree that these processes naturally attenuate a given plume and limit migration from the source depends on the groundwater conditions, aquifer matrix and the type of organic compound. Aromatic volatile compounds such as BTEX may be strongly attenuated through geochemical and biodegradation processes, whereas attenuation of chlorinated solvents and other recalcitrant compounds along the plume flow path may be minor due to low affinity for partitioning to the aquifer matrix and resistance to degradation under many conditions.

The vertical transport of DNAPLs is controlled by (1) the volume and rate of the release, (2) the specific gravity of the liquid, (3) the relative mobility of the constituent (the viscosity and the relative affinity for sediments), and (4) layering or permeability contrasts within the hydrogeologic units underlying the source area. The presence of laterally extensive, low-permeability materials will tend to mitigate the depth of penetration of a DNAPL. The fill and fine-grained alluvial sediments in the vicinity of the ISA tend to be highly stratified, and the resultant permeability contrasts tend to cause spreading of a DNAPL source along the upper surface of low-permeability layers. However, if the DNAPL release encounters discontinuities in low-permeability layers or coarse-grained alluvial sediments, as is expected in an alluvial system such as the Willamette River, penetration to greater depths may occur, which could result in an ongoing dissolved plume source in the deeper flow systems discharging to the river. Experience at other locations, such as the Port of St. Helens/Pope & Talbot site, has shown that a DNAPL commonly perches and flows on top of the CRBG (see Section 2.1.1) unless or until it encounters a fracture that penetrates the entire basalt flow to the next interflow which allows deeper migration and spreading (GeoEngineers 2000).

Dissolved constituents in groundwater may have a source in a LNAPL or DNAPL mass, in chemicals leaching from soil or buried wastes, or in a spill of a dissolved solution (e.g., process water). Chemical adsorption to soil (or sediment), partitioning between soil/sediment and water, and dissolution to water are closely related processes. The physico-chemical properties (e.g., soil/water partitioning coefficient: K_d; organic carbon partitioning coefficient: K_{oc}) of individual chemicals control, in part, the degree to which a chemical moves from the source material or soil to groundwater. Some chemicals are strongly held by soil/sediments while others have an affinity for water. These same properties also affect how chemicals partition between soil or sediment and surface water. For organic chemicals, the K_{oc} of the chemical and the organic carbon fraction of the soil or sediment will generally govern the degree to which chemicals are sorbed to soil or sediment. For example, PCBs and HPAHs have relatively high K_{oc} values and are strongly sorbed to soil or sediment while LPAHs and chlorinated solvents have lower K_{oc} values and more readily partition to the water phase. Because soil sources and groundwater (and sediment sources with overlying surface water) are not in equilibrium due to continual dilution with fresh (clean) water and diffusion of chemicals, the dissolution process is ongoing rather than static, and the more mobile constituents will be desorbed and transported away, reducing the overall mobility of the remaining material. Inorganics also undergo leaching and dissolution but unlike organics their soil/water partitioning coefficients (K_d) are not influenced by organic carbon. Instead, metal solubilities and adsorption can vary widely and are controlled by oxidation state, speciation, associated counter ions, water pH and oxidation-reduction potential, soil particle size, the presence of chelating agents and ligands, and type of mineral phases present.

Other release mechanisms include sediment resuspension and transport, sedimentation of suspended particulates from surface water, chemical precipitation of dissolved constituents from surface water, and groundwater discharge to the Transition Zone. These mechanisms are discussed in the next section, because although they can be post-primary release mechanisms, they are mainly inter-media transport mechanisms.

5.1.3 Transport Media and Mechanisms

Sediment, surface water, groundwater, resuspended soil, and airborne particulates (i.e., dust) are the primary media in the ISA by which chemicals are moved from source areas to locations where exposure to receptors occurs. The physical and chemical processes that govern the movement and interactions of these media also control the movement of chemicals into and through the ISA.

Sediment Transport

Sediment transport (deposition, resuspension, redeposition) is an important mechanism in the LWR physical system. Sediments containing chemicals can be resuspended and redeposited many times within the LWR. With each sediment transport cycle, the concentrations of chemicals in the sediment are modified by incorporation of sediment containing concentrations reflective of upstream areas.

This process is anticipated to substantially attenuate chemical concentrations in sediment with increasing distance from sources.

The movement of sediment through the Portland Harbor navigation channel appears to be controlled, in large part, by the physical shape of the river, both the cross-sectional area and anthropogenic factors (borrow pits and dredged areas). Upstream of the ISA from Willamette Falls to about RM 11, the river tends to be narrow with sustained current speeds that apparently prevent all but the coarsest material from being deposited for the long term in the main stem of the river. From RM 11 to RM 10, the river broadens considerably and suspended and bedload material tends to deposit in a depositional reach that extends from about RM 10 to about RM 7, particularly in the deeper depressions. From RMs 7 to 5, the river cross-section again narrows and suspended sediments are likely transported through this reach, while the degree of bedload sediment deposition and transport is likely a function of temporally varying hydrology. The channel in the lower part of the ISA, RMs 5 to 3.5, again widens and appears to be depositional. Downstream of the ISA, the broad, depositional channel continues to around RM 1.5; the river then narrows again and becomes more dynamic as it reaches the Columbia.

In off-channel, nearshore areas, the general trends described above for the channel are altered by local riverbank morphology, bank treatments, and anthropogenic factors. The elevation change maps produced by comparing the winter 2001/2002 and summer 2002 bathymetry surveys (see Map 2-7) indicate that:

- Areas of shoaling and deepening are more widespread in shallow nearshore areas than in the main navigation channel.
- Many areas of nearshore deepening appear to be closely associated with pier structures, berthing areas, or slips and are likely the result of anthropogenic factors (e.g., prop wash).
- Bridge footings create localized areas of deep scour and accretion.
- An apparently natural stretch of nearshore shoaling extends along the west side of the river in the ISA from RMs 4 to 5, while a stretch of natural nearshore scour extends along the west side of the river downstream of the ISA from RMs 0 to 3.

In general, particulates from upstream sources that are transported into the ISA would be expected to accumulate in depositional areas of the ISA. Depositional areas would be expected to contain chemicals that are characteristic of historic and ongoing upstream sources, in addition to any ISA-related sources. Depending on temporally varying flow conditions, some portion of the suspended sediments that enters the Portland Harbor would settle out in depositional areas. Suspended sediments also likely pass through the Portland Harbor, especially during high-flow velocity events.

It is also evident that impacted sediments (originating upstream or from within the ISA) have the potential to be disturbed and resuspended by anthropogenic factors, such as prop wash and dredging. Their subsequent transport and fate would be a function of the LWR flows at the time of disturbance. Finally, despite the apparently dynamic sediment transport environment in the ISA, the relative magnitude and areal extent of impacted sediments near documented contaminated sediment areas have tended to be consistent over time, suggesting that there are subareas in the system that may be relatively stable. The spatial and temporal sediment transport patterns in the ISA will be further evaluated during the RI/FS.

In addition to direct measurements of riverbed elevation change through time-series bathymetry, a hydrodynamic and sediment transport model will be developed as part of the physical CSM refinement process. A major objective of the model will be to supplement this view of sediment transport in the ISA and LWR. In particular, sediment transport patterns in both major flood and non-flood years will be modeled. The modeling results and other Round 2 sampling (surface and subsurface sediment chemistry) will be evaluated, and these data will be used to refine the physical CSM.

Surface Water

Chemicals may be transported in surface water as suspended particulates, dissolved constituents, and oily films. Chemicals in surface water may originate from upstream sources, direct discharges or releases within the ISA (e.g., outfalls, groundwater discharges), deposition from the air, or resuspension of sediment within the ISA (described under Sediment Transport above). Suspended particulates in surface water are most likely to settle from the water column in relatively quiescent areas of the ISA (e.g., Swan Island Lagoon). During higher rates of flow in the LWR, coarser particulate material that is normally deposited as sediment may be temporarily suspended and added to the water column load. Similarly, water column loads during stormwater runoff events will be higher in the vicinity of discharge points, such as outfalls. Dissolved constituents generally remain in the water column except where chemical or biological processes cause precipitation or adsorption. Volatilization and photolysis may also transform some chemicals in the upper portion of the water column.

Groundwater

Groundwater-related components of the RI/FS will focus on understanding the potential for contaminated groundwater to affect sediments and surface water in the Willamette River. Dissolved chemicals in groundwater most likely will be transported toward the river by groundwater flow. As described in Section 2.1.3, groundwater in the vicinity of the ISA discharges via seeps above the water line or to the Transition Zone below the water line (Figure 5-2a; see Section 2.1.4). Transport of dissolved chemicals of interest (COIs) in groundwater is controlled by advective processes related to the physical hydrogeology (i.e., gradient, permeability) and the physicochemical properties of the chemical(s) and materials in the saturated zone, as well as the plume source and initial concentration in the plume.

Impacted groundwater entering the river could affect chemistry in sediments (including Transition Zone water and the sediment matrix) and in the water column. However, due to the large flow volumes in the river, effects of groundwater constituents on the overall surface water column concentrations are expected to be minimal due to dilution, except adjacent to the sediment/surface water interface in groundwater discharge zones. The effect of groundwater discharges on near-sediment surface water will be conservatively assessed through evaluation of chemical concentrations in water within the bioactive zone. The potential effects in the bioactive layer of the Transition Zone are more likely to be important in evaluating the relative risk to aquatic receptors, and to risk management decisions.

Behavior of chemicals in groundwater is important to the evaluation of potential transport and exposure. Chemicals in groundwater may partition to sediments or pass through the sediments to impact the Transition Zone water and/or surface water. The partitioning process is complicated and depends on the geochemistry of the sediment matrix and the groundwater, as well as the type of chemical. Halogenated and aromatic VOCs, low molecular weight (three or fewer aromatic rings) PAHs and certain species of metals generally exhibit a relatively low affinity for sediments and thus will pass through soil and sediment in the absence of other transformation or attenuation processes. However, these more mobile compounds may partition to aquifer materials and sediments under certain conditions (e.g., from anaerobic zones to more oxygenated zones). Other chemicals, such as pesticides, high molecular weight (four or more aromatic rings) PAHs and some metals, tend to adsorb or bind to soils or sediments, particularly where organic carbon is present, and may have lower tendency to be transported in aqueous phases or to partition from sediments to Transition Zone water. However, transport of these types of chemicals may be enhanced, on occasion, under certain geochemical conditions, in the absence of organic carbon, or in certain instances where the presence of another chemical increases the mobility of the chemical, thereby increasing the potential to be transported to the Transition Zone.

The assessment of potential impacts to the Transition Zone water and surface water from chemicals in groundwater will require evaluation of fate and transport characteristics of site-specific contaminants in groundwater on a site-by-site basis. The chemical attributes discussed above are described in more detail in Section 7.2.3 as they relate to the proposed approach for evaluating risk from groundwater COIs.

Four potential groundwater chemical transport scenarios relevant to the project have been identified (see Figure 5-2b). The scenarios are described below:

1. **Impacted groundwater from an upland source that flows through clean sediment:** In this scenario, some portion of the chemicals transported in groundwater partitions to sediments, potentially causing sediment-related impacts, or flows in the dissolved phase to potentially cause impacts to Transition Zone water or the surface water column. The potential impact to

sediment, Transition Zone water, and the water column depends on the concentration(s) of the chemicals in groundwater as well as the affinity of each chemical for the sediments. The greatest impacts to sediments and Transition Zone water occur where a NAPL is transported to the river through sediments or where the source of groundwater constituents is located near the river and high contaminant concentrations in groundwater are observed. In general, an aqueous-phase plume with a long flow path from its source to the river will likely have relatively less effects than a plume with its source near the river, as partitioning and transformation processes will reduce the concentrations prior to reaching the Transition Zone. Section 7.2.3 describes the approach for assessing chemicals in groundwater at concentrations of concern that partition to the solid or aqueous phase within this zone.

2. **Subareal surface seepage of impacted groundwater:** This scenario refers to shallow impacted groundwater that comes to the ground surface above the water line and then discharges to the river as a seep. After the groundwater discharges to the ground surface as a seep, it is available for human contact and is the only groundwater pathway that may result in potentially complete exposure pathways.

3. **Impacted groundwater from an upland source flows through impacted sediments:** In this scenario, impacted groundwater mobilizes chemicals from impacted sediments and advects in the dissolved phase to potentially cause impacts to sediment or water within the Transition Zone.

4. **Clean groundwater flowing through impacted sediments (no upland chemical source):** In this scenario, chemicals present in buried sediments may partition to groundwater flowing through the sediments toward the river. Some chemicals could then repartition to the shallower sediments further along the flow path and/or potentially cause dissolved-phase impacts to water within the Transition Zone. This scenario also is a potential mechanism of contamination to overlying clean sediments (if in a depositional area) or a sediment cap. The impact of this scenario depends on the characteristics of the buried contaminated sediments and groundwater flux rates. In more permeable sediments, the concentrations in groundwater will be limited by partitioning rates from the sediment source. The impacts to overlying sediments under this scenario are expected to be relatively low where sediment sources have been present for several decades and do not include NAPL.

Soil

Resuspended soil is not considered to be a very substantial transport medium in the ISA given the highly developed nature of the harbor area. Runoff and slope processes may transport soil downhill toward the shoreline along the steeper riverbanks that are not vegetated or covered with engineered structures. In limited locations, soil transport may move impacted soil to elevations that are more frequently affected by the river.

Airborne Particulates

The transport of chemicals by airborne particulates is not considered to be a very substantial transport mechanism in ISA.

5.1.4 Exposure Media

As shown in Figure 5-1, the exposure media in the physical CSM are surface water, sediment, water within the Transition Zone, and biota. Chemicals that are either in dissolved or particulate form may be concentrated in surface water, bedload, suspended sediments, or water within the Transition Zone in the ISA. From these physical media, chemical constituents are potentially exposed to ecological (Section 5.2) and human (Section 5.3) receptors of concern, which represent the exposure endpoints in the CSM for the ISA.

5.2 ECOLOGICAL CONCEPTUAL SITE MODEL

This section summarizes the current understanding of the potential exposure routes and pathways from affected media to ecological receptors in the ISA. The preliminary ecological CSM (Figure 5-3) identifies the sources, release mechanisms, exposure media and routes, and potential receptors, and characterizes the various exposure pathways for potential ecological receptors within the ISA. The physical CSM, described in Section 5.1, provides a preliminary identification of sources, release mechanisms, and exposure media. The rationale for selecting the ecological receptors and exposure pathways is included in Appendix B. An understanding of the ecological CSM is needed to complete the ecological risk assessment (ERA).

Data provided by the Round 1 sampling program will facilitate a preliminary understanding of the potential ecological risks associated with exposure to chemicals in sediment and tissue. A preliminary risk evaluation report will be developed following Round 1. Additional data will be collected in subsequent rounds of investigations. This information will advance the current understanding of the ecological CSM, which will continue to be revised based on additional data.

The majority of the ISA is industrialized, with modified shoreline and nearshore areas. Wharves and piers extend into the channel, and bulkheads and riprap revetments armor the riverbank. Dredging has produced a uniform channel with little habitat diversity. However, some segments of the ISA, as well as areas upstream and downstream of the ISA, are more complex with side channels, shallow water areas, and less shoreline development, providing habitat for a suite of local fauna. A description of the general types of habitat in the LWR available to ecological species is presented in Appendix B.

5.2.1 Potential Ecological Receptors

Various organisms are present in the ISA (see Appendix B), with each organism relating to its environment in unique ways that determine its exposure to chemicals. Though each species has unique habitat requirements and behavior, several species are often similar in their use of resources and potential exposure to chemicals. Thus, representative species from each group are selected to typify other species with similar exposure. In this preliminary ecological CSM, potential ecological receptors are grouped into aquatic plants, benthic invertebrates, fish species, amphibians, reptiles, birds, and mammals.

The rationale for selection of representative species is presented in Appendix B. Example food web diagrams for fish and wildlife are presented in Figures 5-4 and 5-5, respectively. A summary of the potential receptor groups is provided below.

Aquatic Plants

Aquatic plants were identified within the ISA in the Round 1 reconnaissance survey (see Appendix B, Attachment B2). Therefore, aquatic plants are exposed to potentially impacted sediment and surface water and will be assessed as a population to the extent possible. A discussion of aquatic plants is presented in Appendix B.

Benthic Invertebrates

Benthic invertebrates are typically evaluated at the community level because many species are collocated in a localized "community" with little to no movement occurring within the habitat. Therefore, a community-level assessment of benthic invertebrates will be conducted in Portland Harbor. A population-level assessment will also be conducted, as feasible. However, due to practical limitations and the available exposure and toxicity information, the population assessment will likely be more qualitative. Remedial decisions will be based on a community assessment.

The details of the epibenthic and infaunal invertebrate community assessment are presented in Appendix B, Attachment B4. In addition, as representative macrofauna, crayfish will be assessed separately in the preliminary and baseline risk assessments because they have relatively longer life spans than other invertebrates and they consume detrital material. Likewise, mollusks will be assessed, but separately

Fish Species

Consistent with the criteria and rationale presented in Appendix B and with EPA (1998) guidance, representative fish species were selected and approved by EPA for the baseline ERA. The representative species are presented below by feeding guild:

- **Herbivores/Omnivores:** The largescale sucker was selected to represent omnivorous and herbivorous fishes because of its close association with sediments.
- **Invertivores:** Juvenile chinook salmon was selected to represent anadromous invertivorous fish species because it is a federally listed threatened species occurring in the ISA. Sculpin was selected to represent resident invertivorous fish species because of its close association with sediments and small home range. In addition, the peamouth was selected to represent resident insectivorous fishes, feeding similarly to the juvenile salmon, but spending more time in the ISA.
- **Piscivores:** The northern pikeminnow was selected as a representative of piscivores because it is long-lived and feeds at the top of the food chain. Smallmouth bass was also selected as a representative species for piscivores because of their smaller home-range size relative to northern pikeminnow.
- **Detritivores:** Juveniles (ammocoetes) of the Pacific lamprey were chosen as the representative species for detritivorous fish species. The ammocoete also represents a sensitive life-stage.

Amphibians and Reptiles

Amphibians were identified in selected locations within the ISA during the Round 1 reconnaissance survey (see Appendix B, Attachment B2) and were selected as a receptor group. Amphibians will be evaluated in areas where they may breed within the ISA (e.g., where a sensitive life-stage may be exposed). Amphibians have been selected as a surrogate for reptiles because amphibian exposure to chemicals is expected to be higher than reptiles, amphibians tend to be more sensitive, and toxicity information for reptiles is less abundant than for amphibians.

Birds

The osprey was chosen as the representative species for the piscivorous birds. Additionally, the bald eagle will be evaluated at the individual level because it is a federally listed threatened species occurring in the ISA. Sediment-probing invertivorous birds are represented by the spotted sandpiper. The spotted sandpiper is also considered a conservative surrogate species for omnivorous birds. The hooded merganser was chosen to represent diving birds. Herbivorous birds have limited exposure to chemical constituents in the LWR, and estimated total exposure for sediment-probing invertivores is assumed to be a conservative estimate of total exposure to herbivorous birds.

Mammals

Mink were selected to represent carnivorous mammals that may use the ISA.

5.2.2 Potential Exposure Pathways

This section describes the potential chemical exposure pathways to species in the ISA and discusses which pathways will be evaluated for the various receptor species in the ERA. Representative species can be exposed to chemicals in water or sediment in the ISA either directly through contact with sediments, water within the Transition Zone, or surface water or indirectly through the food chain. The CSM (Figure 5-3) illustrates the pathways that chemicals may follow from primary sources to the ecological species. Exposure pathways were designated as follows:

- **Complete and Major:** Pathway is complete and expected to be a significant contributor to total exposure. This pathway will be quantitatively assessed, when possible, in the preliminary risk evaluation or baseline risk assessment.
- **Complete and Minor:** The pathway is complete and expected to be a minor component of total exposure. In relation to other complete pathways, chemical exposure is expected to be minimal. This pathway will not be quantitatively evaluated in the preliminary risk evaluation or baseline risk assessment unless sufficient data are available, but will be discussed qualitatively to a level of certainty dependent on available studies. If the data are insufficient, additional information will be gathered through an interim sampling process and the risk evaluated if the pathway is believed to potentially contribute significantly to overall risk.
- **Complete and Uncertain:** The pathway is complete but of undetermined significance. If there are insufficient toxicological data, this pathway will not be quantitatively evaluated in the preliminary risk evaluation or baseline risk assessment, but will be discussed qualitatively to a level of certainty dependent on available studies. However, if the uncertainty is due to lack of site-specific data, appropriate information will be collected and a determination made whether the pathway is major or minor. If sufficient toxicological data exist, the pathway will be evaluated using multiple lines of evidence, including sediment chemistry, bioassays and an evaluation of groundwater contribution.
- **Incomplete:** The pathway is incomplete; therefore, it will not be evaluated in the preliminary risk evaluation or baseline risk assessment.

The specific exposure pathway assignments are summarized by receptor in the remainder of this section.

Aquatic Receptors

Aquatic Plants

Aquatic plants actively and passively transfer chemicals from surface water and sediments; therefore, these contact pathways are considered the only complete pathways of exposure to these receptors in the ISA.

Benthic Invertebrates

Infaunal and Epibenthic Invertebrates

Infaunal and epifaunal benthic invertebrates are generally in direct contact with sediments and surface waters. Therefore, direct sediment and water contact are considered complete and major pathways of exposure (Figure 5-3). Surface water ingestion is considered a complete and minor pathway of exposure for infaunal and epifaunal invertebrates. The sediment ingestion pathway is considered complete and major. Biota ingestion for infaunal and epifaunal organisms is also considered a complete and major pathway of exposure.

The influence of groundwater on Transition Zone water quality in the ISA cannot be determined at this time due to lack of Transition Zone water data within the ISA. Direct contact with water within the Transition Zone is considered a complete and uncertain pathway for benthic infauna. The Transition Zone water pathway will be assessed if the results of the groundwater evaluation indicate effects on water quality within the Transition Zone and potentially complete pathway to benthic infauna (see Section 7.3). The Transition Zone water pathway would only potentially affect benthic infauna in the biologically active zone. For all other receptors, this pathway is considered incomplete.

Mollusks

Direct sediment, Transition Zone water, and surface water contact are considered complete and major pathways of exposure for mollusks (Figure 5-3). Sediment ingestion is also considered a complete and major pathway of exposure for mollusks because they are known to routinely ingest sediment. Water ingestion is considered a complete and minor pathway. Biota ingestion is considered a complete and major pathway because mollusks' diets can consist of other benthic organisms and detritus.

Epibenthic Macrofauna

Crayfish are in direct contact with surface water and sediments, and this pathway is considered complete and major (Figure 5-3). Crayfish ingest sediments directly and indirectly; therefore, this pathway is considered complete and major. Surface water ingestion is considered a complete and minor pathway of exposure. Finally, crayfish diets consist of other benthic organisms, detritus, and dead fish. Therefore, biota ingestion is considered a complete and major pathway of exposure.

Fish

Omnivore/Herbivore **-** *Largescale Sucker*

Direct contact with sediments, sediment ingestion, and ingestion of benthic biota are considered to be complete and major pathways of exposure for the largescale sucker (Figure 5-3). In addition, largescale suckers are in direct contact with surface water, thus, this pathway is also considered a complete and major pathway of exposure for this receptor. Incidental ingestion of water may occur for the largescale sucker, as for all the fish species; however, this pathway is considered complete and minor.

Invertivore - Sculpin Species

Direct sediment and surface water contact are considered complete and major pathways of exposure for sculpin (Figure 5-3). Water ingestion is considered a complete and minor pathway. Because sculpin may prey upon sediment-ingesting organisms such as epibenthic invertebrates, sediment and biota ingestion are also considered complete and major pathways of exposure.

Invertivore - Peamouth

Peamouth are in constant contact with surface water and this pathway is considered complete and major (Figure 5-3). Ingestion of surface water is a complete and minor pathway. The diet of the peamouth consists of benthic invertebrates, crustaceans, and small fish. Therefore, the ingestion of biota is a complete and major pathway. While feeding, peamouth may ingest sediments directly through their mouth or indirectly through their prey. The amount of sediments ingested with prey could be significant when peamouth feed on benthic organisms. However, fish species are also a portion of the peamouth diet. Therefore, this pathway is considered complete and uncertain. Peamouth are benthopelagic species and direct contact with sediment will occur when feeding on benthic prey. However, benthic species comprise only a part of the peamouth diet, and peamouth spend a significant portion of time in the pelagic zone. Therefore, direct contact with sediments is considered a complete and minor pathway.

Invertivore - Juvenile Chinook Salmon

Surface water contact is considered a complete and major pathway of exposure (Figure 5-3) for juvenile chinook salmon. Ingestion of prey is also considered a complete and major exposure pathway. The sediment ingestion pathway is considered complete and uncertain. The sediment ingestion pathway for metabolized chemicals will be addressed qualitatively. Direct contact between juvenile chinook salmon and sediments, and ingestion of surface water, are assumed to be complete and minor pathways.

Piscivore - Smallmouth Bass

Ingestion of biota is considered a complete and major pathway of exposure (Figure 5-3) for the smallmouth bass. The ingestion of water is considered a complete and minor pathway of exposure. Smallmouth bass are in constant contact with water. Thus, direct contact with surface water is a complete and major pathway of exposure. Direct sediment contact and ingestion are considered complete and minor pathways.

Piscivore - Northern Pikeminnow
Northern pikeminnow are in constant contact with surface water, and this pathway of exposure is considered complete and major (Figure 5-3). Adult northern pikeminnow primarily consume fish. Thus, ingestion of biota is considered a complete and major pathway of exposure. Northern pikeminnow, like smallmouth bass, is a benthic-pelagic species and will be occasionally in direct contact with the sediment and may ingest some sediment directly and indirectly from their prey. Ingestion of surface water and sediment and direct contact with sediment are all considered complete and minor exposure pathways.

Detritivore - Pacific Lamprey Ammocoetes
Pacific lamprey ammocoetes live in direct contact with sediments and often filter food (e.g., detritus, diatoms) directly from sediment. Therefore, direct sediment contact and ingestion of sediments and biota are considered to be complete and major pathways of exposure for Pacific lamprey ammocoetes (Figure 5-3). In addition, surface water contact is also considered complete and major pathways of exposure for this species. Ingestion of surface water is a complete and minor pathway.

Amphibians and Reptiles
Direct contact with surface water is considered a complete and major pathway to amphibians. Direct contact with sediment is considered a complete and uncertain pathway to amphibians and reptiles. The food ingestion pathway is considered complete and major for both amphibians and reptiles. Surface water ingestion is considered a complete but minor pathway for amphibians and reptiles.

Wildlife Receptors

Birds

Piscivore - Osprey and Bald Eagle
Food ingestion is considered a complete and major pathway of exposure for the osprey and bald eagle (Figure 5-3). Sediment ingestion is considered a complete and minor pathway of exposure for bald eagle. Because surface water contact and ingestion and direct sediment contact are likely to be minimal, these pathways are considered to be complete but minor pathways.

Diving Carnivore/Omnivore - Hooded Merganser
Food ingestion is considered a complete and major pathway of exposure for the hooded merganser (Figure 5-3). Sediment ingestion is also considered a complete and major pathway. Surface water contact and ingestion and direct sediment contact are considered incidental occurrences and complete but minor pathways of exposure.

Sediment-probing Invertivore/Omnivore - Spotted Sandpiper
Food ingestion is considered a complete and major pathway of exposure for the spotted sandpiper (Figure 5-3). In addition, sediment ingestion is considered a complete and major pathway of exposure. Surface water contact and ingestion are

considered complete but minor pathways. Direct sediment contact is considered a complete but uncertain pathway.

Mammals

Carnivore - Mink

Food ingestion by mink is considered a complete and major pathway of exposure (Figure 5-3). Sediment ingestion is considered a complete and major pathway of exposure for carnivorous mammals. Surface water contact by swimming and ingestion is considered complete and minor. Direct contact with sediment is considered complete and minor.

Additional data provided by Round 1 and later sampling programs will be used to further characterize the ecological risks associated with exposure to chemicals in sediments, water, and tissues and to refine the ecological CSM.

5.3 HUMAN HEALTH CONCEPTUAL SITE MODEL

This section summarizes the current understanding of the physical and biological setting of the ISA as it pertains to potential impacts to human health. The CSM for human exposures, based on the current understanding of conditions in the ISA, is presented in Figure 5-6. The rationale for selecting human receptors and exposure pathways is included in Appendix C.

The CSM graphically depicts possible sources of chemicals, possible chemical-affected media, mechanisms of chemical transfer between media, receptors that may be exposed to chemicals associated with the ISA, and potential exposure pathways. Possible sources of chemicals and possible mechanisms of chemical migration and transfer are described in the physical CSM (see Section 5.1). The human health CSM focuses on potential human receptors and potential exposure pathways to those receptors. Only exposure pathways that are theoretically complete and potentially significant (including those pathways of uncertain significance) will be evaluated quantitatively in the baseline human health risk assessment (HHRA).

Data provided by the Round 1 sampling program will allow a preliminary understanding of the human health risks associated with exposure to chemicals in beach sediment and tissue. Additional data will be collected in subsequent rounds of investigations. This information will advance the current understanding of the human health CSM, which will continue to be revised based on additional data.

5.3.1 Potential Human Receptors

Potentially exposed populations were identified based on consideration of current and future uses of the Site and EPA (1989) guidance. The potential current and future human receptors identified below represent those receptors that are anticipated to be present under current and reasonably foreseeable future conditions. The selected receptors are anticipated to be protective of other potential receptors that will not be evaluated quantitatively in the baseline HHRA. As shown in the CSM, the receptors for current and future uses include the following:

- Dockside worker
- Transient
- Recreational beach user
- Recreational fisher
- Native American consumption fisher
- Non-Tribal high consumption fisher.

The receptors were identified based on human activities that are known to occur within the ISA. It is assumed that the recreational beach user, which includes exposure to surface water during swimming activities, will be protective of divers in Portland Harbor. This assumption will be reassessed when additional information regarding divers in Portland Harbor becomes available, and, if needed, a diver receptor may be included in the HHRA.

5.3.2 Potential Exposure Pathways

Exposure pathways are defined as the physical ways in which chemicals may enter the human body (e.g., ingestion, inhalation, dermal absorption). A complete exposure pathway consists of the following four elements:

- A source of chemical release
- A retention or transport medium (or media in cases involving media transfer)
- An exposure point (a point of potential human contact with the contaminated medium)
- An exposure route (e.g., ingestion, dermal contact) at the exposure point.

If any of the above elements is missing, the pathway is considered incomplete and exposure does not occur.

As discussed in Section 4, the currently known and identified affected media in the ISA are sediment and water. In addition, some chemicals in sediment may be taken up by bottom-dwelling organisms. As fish species feed on these organisms, the chemicals may bioaccumulate in the fish tissue. The potential exposure pathways identified are:

- Ingestion of sediment and surface water
- Dermal contact with sediment and surface water
- Ingestion of fish and shellfish.

The baseline HHRA will focus on potential exposures occurring within the ISA, and areas outside the ISA that are identified by the RI process, to quantify risks to human receptors. However, certain receptors may also be exposed to media at upland sites adjacent to the ISA. The baseline HHRA will acknowledge that additional upland exposures may occur, and these potential risks will be addressed by DEQ through upland activities.

Each scenario is described in detail in Section 3 of Appendix C. Potentially complete and significant or potentially complete and significance unknown exposure pathways shown in Figure 5-6 will be evaluated quantitatively. Pathway designations and the rationale for each pathway for each receptor are also explained in Section 3 of Appendix C.

Current and Future Dockside Worker
Industrial and commercial workers at facilities near the river are exposed to sediments and water only when they are conducting site-specific activities within natural river beach areas. These activities generally occur infrequently, but they may provide opportunities for industrial and commercial workers to have dermal contact with and/or incidental ingestion of intertidal sediments (river beach sediments located between the high- and low-water lines). Dermal contact with or ingestion of water that may occur during occupational activities would be unintentional and infrequent. Dockside workers do not consume fish through occupational activities.

Current and Future Transients
During past site tours, tents and makeshift dwellings were observed as evidence that individuals were occupying some riverbank areas. These transients may have dermal contact with water and intertidal sediments within natural river beach areas they are utilizing. Incidental ingestion of surface water and intertidal sediments may also occur through activities of these transients, and transients may be using the river as a source of drinking water. Transients may also be consuming fish and shellfish; however, no information is available regarding this potential exposure pathway, and it will not be evaluated under this scenario, but is considered a potential data gap.

Current and Future Recreational Beach User
Adults and children use the LWR for boating, water skiing, swimming, and other water activities. Ongoing, long-term, repetitive beach use will be the focus of the baseline HHRA, as it is anticipated to result in the greatest risk as compared with other recreational receptors. Recreational beach users may have dermal contact with, and incidental ingestion of, water and intertidal sediments during activities within river beach areas. Recreational beach users do not consume fish through beach use activities.

Current and Future Fishers

Three fisher receptors (recreational fishers, Native American consumption fishers, and non-Tribal high consumption fishers) will be evaluated in the baseline HHRA. The fisher categories are differentiated by the frequency of fishing and by the amount of fish consumed. Each scenario is described in detail in Section 3 of Appendix C. Fishers may consume fish and shellfish that are caught from the Site and may also have dermal contact with, and incidental ingestion of, sediments at banks within the Site where fishing occurs, and in water. Dermal contact with or ingestion of water that may occur during fishing activities within the Site would be infrequent.

Potentially Overlapping Scenarios

Potential risks will be quantified for each receptor; however, certain individuals may participate in activities resulting in potential exposures under more than one category (e.g., recreational beach users may also be recreational fishers). The combination of exposures for an individual through different receptor categories will be evaluated further in the baseline HHRA.

6.0 OVERVIEW OF PORTLAND HARBOR RI/FS PROCESS

This section presents the overall process for completing the RI/FS and ultimately obtaining a Record of Decision (ROD) for the Site. It describes in general terms the major milestones that will be achieved during the RI/FS process. While this section provides the general accomplishments for each of the major milestones and how the milestones relate to each other, the specifics of how these milestones will be achieved are presented in Sections 7 and 8.

In order to develop an approach for obtaining a ROD, the LWG and EPA first defined the objectives for the ROD and the major issues that the ROD may address. Next, the LWG identified the types of information needed to accomplish those objectives and address the issues. Finally, the LWG grouped information needs into logical sequences or phases of work. These work phases support major milestones such as the RI, ERA, HHRA, and FS. The LWG and EPA refer to this process as a "road map," as it details the paths and tasks along those paths necessary for completing the RI/FS and ROD.

It is anticipated that four rounds of data collection efforts conducted by the LWG will be used in conjunction with the Category 1 historic information to provide the site-specific data needs to complete the RI, baseline risk assessment, and FS reports:

- Data collected prior to signing of the AOC (pre-AOC)
- Data collected in Round 1
- Data to be collected in Round 2
- Data to be collected in Round 3.

However, additional sampling rounds may be required to address data gaps identified as a result of technical memorandum development, review of Round 1 data, Round 2 data, or review of relevant new data or information.

The objectives of these sampling efforts, described in Section 6.2, generally include obtaining sufficient information to assess site-wide risk and understand the distribution of chemical constituents sufficient to support the development of the RI and baseline risk assessment reports. As with most CERCLA projects, these documents will be the transition point to the FS. The fourth round of data collection (referred to as Round 3) will focus on providing information for the FS, but will also serve as a final opportunity to address any outstanding site characterization or risk characterization issues. The completion of the Round 3 sampling effort will lead to the draft FS report.

Several important procedural steps are required prior to the ROD, such as approval of the FS, development of a draft proposed plan for public review and comment, and completion of a final proposed plan. For this road map to be successful, it is important that all of the parties understand the objectives of each sampling and data evaluation round and how these objectives will be accomplished (i.e., what data will be collected and how those data will be evaluated).

6.1 PRELIMINARY REMEDIAL ACTION OBJECTIVES

Data needs for assessing the distribution of in-river chemicals, human health and ecological risks, and for developing remedial alternatives for the ISA were identified based on a review of preliminary remedial action objectives (RAOs) historical data and information developed as part of EPA's (2000a) DQO process. A technical memorandum that presents preliminary RAOs for this site is summarized in Section 8.2 and found in Appendix A, Attachment A1. Specific definitions of the terms used in the preliminary RAOs are provided in Section 8.2 and the attachment.

Preliminary RAOs that were used to identify the categories of data that will be needed to fulfill project objectives include the following:

1. Reduce human health risks from direct contact with and incidental ingestion of chemicals of concern (COCs) in sediments in the Site to acceptable levels.
2. Reduce COC concentrations in sediments in the Site to levels that will result in acceptable risks to humans that eat fish and shellfish from the Site.
3. Reduce human health risks from direct contact with and incidental ingestion of COCs in water in the Site to acceptable levels.
4. Reduce ecological risks from contact with and ingestion of COCs in sediments or prey in the Site to acceptable levels.
5. Reduce ecological risks from contact with and ingestion of COCs in water in the Site to acceptable levels.

It is anticipated that these preliminary RAOs will be refined throughout the data collection and evaluation phases of the project; however, the preliminary RAOs are considered sufficient to identify the needed data types for Round 2 sampling. Round 3 data types will also be developed using these RAOs and the results of the Round 2 sampling effort. The categories of data that will be required to complete the RI/FS include sediment and tissue chemistry, sediment toxicity data, physical sediment characteristics, surface water chemistry and conventional parameters, habitat type and distribution, species occurrence, , hydrodynamic/sediment transport processes, sources (including upland and outside of the ISA), and source control status.

6.2 OBJECTIVES OF THE RI/FS

The Site is complex and includes multiple potentially responsible parties (PRPs), potential ongoing sources both upstream and within the ISA, potential locations that could become early remedial actions implemented as non-time critical removal actions under their own AOCs (i.e., Early Actions), and an existing PRP group (the LWG) that is funding the RI/FS required by the current AOC. As a result, the ROD must anticipate how a remedial action can be determined and implemented given all of the complexities associated with the Site.

Sources of contamination to Portland Harbor may contribute localized areas of risk exceeding acceptable levels. Sources include stormwater discharges, groundwater discharges, atmospheric deposition, and non-point source runoff. If it is determined that these sources contribute to unacceptable risk to the site, a combination of upland source control measures and/or in-water remediation measures may be required. The RI/FS must gather sufficient data for the human health and ecological risk assessments to evaluate the risks associated with the release, discharge, or emission of these sources to Portland Harbor.

Consistent with EPA's memorandum, Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites [OSWER Directive 9285.6-08 (EPA 2002b)], a risk-based framework for characterizing the Site, evaluating options for sediment remediation, and developing the ROD forms the basis of this Work Plan.

First of all, it is important to note that the RI will not be considered complete until:

1. Potential sources have been identified,
2. The nature and distribution of chemical constituents (vertical and lateral) that pose risk is defined for both river-wide and localized areas of contamination, and
3. River dynamics and contaminant transport are understood in sufficient detail to evaluate sediment stability and potential impacts associated with individual sites and their contribution to Portland Harbor.

Based on information collected to understand the distribution of chemical constituents, risk assessments and evaluations will provide important input to the ROD. The baseline ecological and human health risk assessments will estimate risks to ecological receptors and human health. The results of the baseline risk assessments will be used to identify and delineate preliminary SMAs in which sediments may present unacceptable risks. (Section 8.6 describes how SMAs will be delineated in more detail.) After preliminary SMAs are identified, the FS will develop a list of potential remedial alternatives. The evaluation of remedial alternatives may include an evaluation of relative risks associated with each alternative. The overall risk-based approach to the RI/FS is summarized in Figure 6-1.

According to the National Contingency Plan, the overall goal of the RI/FS process is protection of human health and the environment from adverse effects of hazardous substances. Risk assessment plays a central role in the site characterization and potential cleanup associated with any RI/FS project. The purpose of a risk assessment is to characterize the risks posed by hazardous substances. This information is required to make risk management decisions related to the Site. The results of the risk assessment are then used to evaluate remedial alternatives and to establish cleanup goals, as appropriate.

In accordance with EPA guidance (1988, 1997, 2002b), the RI/FS for the Portland Harbor Superfund Site will be an iterative process using a risk-based framework for determining risk to human health and the environment from site-related chemicals and for evaluating options for risk reduction from exposure to chemicals in sediment. Interim risk evaluations will be used to focus the remedial investigation. These interim risk evaluations will be based on conservative exposure assumptions and will consider all relevant RI/FS data to understand if (and under what conditions) receptors may be exposed to contaminated subsurface sediment above acceptable risk-based levels.

At the end of the RI/FS, available data must be adequate to allow EPA to make risk management decisions for the Site. Multiple iterations of sampling and analyses are anticipated to allow sufficient characterization of risks to support risk management decisions for the Site. Sampling for each iteration will be determined, in part, based on interim risk evaluations and will be documented in subsequent field sampling plans. Interim risk evaluations will be used to identify additional data needs for the risk assessment, which will be incorporated into the Work Plan and subsequent field sampling plans. These interim risk evaluations will also be used to provide a more complete understanding of exposure pathways and the magnitude of potential exposure and to update the conceptual site model. Additional data collection will be focused on data needed to reduce uncertainties associated with preliminary estimates of risk. Additional data collection may also be required to address data needs identified in subsequent technical memoranda, data gaps identified during sampling rounds 2A and 2B and/or new information relevant to the RI/FS. Exposure estimates per medium will be derived following adequate characterization of that particular medium. The final HHRA and ERA reports will be included in the final RI report.

Once the site has been adequately characterized relative to the nature and distribution of chemical constituents, the media, pathways, and chemicals driving unacceptable risk will be identified in the baseline risk assessment. Prior to development of remedial goals and strategies, an evaluation of potential sources of chemicals driving unacceptable risks will be conducted. Chemicals may be entering the ISA from sources located within the ISA or upstream of the ISA, and some chemicals may be contributed from both ISA and upstream sources. Background levels will be established in accordance with EPA (2002c) and other relevant guidance and will be used in the overall remedial decision-making for the Site. The approach that will be used to establish background levels will be submitted as a technical memorandum to EPA for review. Consideration of background conditions will follow EPA guidance (2002c) as well as other relevant EPA Superfund guidance and regulatory and statutory requirements.

After the evaluation of sources is completed, development of site-specific preliminary remediation goals (PRGs) will occur. PRGs will be developed for those chemicals driving unacceptable risks and having sources within the ISA. PRGs will be used in the delineation of potential remediation areas and will be developed for both ecological and human receptors. The methods and assumptions that will be used to derive the PRGs for both ecological and human health endpoints will be submitted as a technical memorandum to EPA prior to submittal of the baseline risk assessment.

Direct and indirect pathways from sediment will likely be the primary drivers of ecological risks at the Site. Based on the benthic risk approach, sediment PRGs will be derived directly from the predictive effects model and, if possible, the crayfish-to-sediment regression relationship. As a tool for developing sediment PRGs for fish, an approach to estimate the relationship between COI concentrations in sediment and associated tissue will be developed in collaboration with EPA and its partners. A technical memorandum will be submitted to EPA describing the modeling approach to be used for developing PRGs. The possible approaches range from deriving site-specific biota sediment accumulation factors (BSAFs) to adapting a generic aquatic food web model. The model will be calibrated using site-specific data for those parameters that are highly variable between aquatic systems and/or contribute significantly to the output. Literature-derived values will be used to parameterize the model, when necessary. Wildlife PRGs will be based on probable risk levels, using site-specific assumptions regarding wildlife exposure.

For human health, fish consumption will likely be one of the primary risk drivers at the Site. Similar to the approach for ecological risks, a model will be used to develop sediment PRGs based on fish tissue concentrations that result in unacceptable risks to human health. The same model selected to develop the sediment PRGs for the ecological risks will be used to develop sediment PRGs for human health risks resulting from fish consumption. Sediment PRGs will be developed for each of the fish or shellfish species that pose unacceptable risks for human consumption. If needed, sediment PRGs will also be back-calculated for beach areas where direct contact with sediment results in unacceptable risks to human health.

To examine spatial distributions of risk, map layers will be created for each ecological and human health endpoint, depicting areas with sediment concentrations that pose unacceptable risks. Areas of unacceptable risk will be defined using calculated sediment PRGs. The maps will be based on available sediment data of acceptable quality. The maps for each ecological endpoint will be overlaid to define preliminary areas for potential remediation for the purpose of protecting ecological receptors. The maps for target fish and shellfish species for human consumption also will be overlaid to define preliminary areas for potential remediation for protection of human receptors.

The ecological risk-based PRGs and map overlays will be combined with the human health-based PRGs and map overlays to examine differences and similarities in spatial distribution of areas that pose unacceptable risks to ecological and human receptors. Where overlap exists, the lowest PRG will be identified as the target concentration. The areas resulting in unacceptable risks will be identified as preliminary areas of concern to be evaluated in the FS.

This information on sediments will be combined with identified risks from other media, including groundwater present in sediments (or Transition Zone water) and surface water. Risk based-PRGs will also be developed for these media and will be displayed in mapping approaches, as appropriate.

The RI/FS will develop the information to support the following elements for EPA's consideration in developing the proposed plan and ROD:

1. **Sediment Management Areas.** It is recommended that the ROD delineate SMAs based on unacceptable risk to human health or the environment. The delineation will include an estimate of the areal extent based on unacceptable risk. Volumes of sediment with unacceptable risk will also be determined, where appropriate (see below for more detail). The boundaries of the required remediation areas will be refined following the ROD as additional data are collected by responsible parties in the RD/RA phase of work. The process for determining site-specific risk will follow the same rules and processes used in the site-wide risk assessment. It should be noted that contaminated sediments may present area- or site-wide risks that will also be addressed in the FS. It is anticipated that some unacceptable risks determined by the risk assessments will be restricted to generally well-defined sources and areas of relatively high contaminant concentrations (and associated risk), and will be defined as SMAs. It is also anticipated that unacceptable risks will exist over more widespread areas (e.g., chemicals contributing to bioaccumulation risks) and the contribution of each SMA to these site-wide risks will be recognized and described for each SMA.
2. **Early Actions and Operable Units.** It is recommended that the ROD provide the regulatory mechanism to acknowledge and account for the environmental benefit of any Early Actions that have been implemented earlier or that have been approved by EPA at the time of the ROD. Some areas within the Site might be suited for designation as separate operable units where subsequently distinct RD/RA and related tasks would be completed for the particular unit(s).
3. **Remediation Recommendations.** It is recommended that the ROD identify the type of remediation by SMA, according to the conclusions of the FS. For some SMAs, this will likely lead to a suite of remedies that includes dredging,

capping, natural recovery, and institutional controls that are applied in combination across the SMA.

4. **Disposal Options.** For those areas targeted for dredging in the remediation recommendations described above, it is recommended that the ROD identify a menu of viable sediment disposal options and locations. Because the dredging actions may occur over a broad period of time and the volumes will likely vary substantially by SMA, it is advantageous identify a variety of disposal options. To the extent that these options include yet-to-be-constructed or permitted facilities, such as in-water confined aquatic disposal or nearshore disposal facilities, the ROD will rely on the analyses presented in the FS report to substantiate the acceptance of each disposal option. For existing privately or publicly operated landfills, the ROD will rely on a combination of the existing regulatory mechanisms that those facilities have for accepting contaminated dredged material as well as the analyses presented in the FS report.
5. **Sources of Recontamination (Upstream of the Site and Within the Site).** It is recommended that the ROD identify potential sources that are contributing to unacceptable risk. These sources may include inputs from upstream of the Site, within the Site, or in upland areas that may be sources of recontamination of remedies proposed for the Site. Sources of risk within the Site will be identified, and decisions regarding cleanup in the ROD will take into account any necessary source control actions to ensure long-term effectiveness of the remedy.
6. **Integration of ROD with NRDA.** To create efficiencies between the CERCLA and the National Resource Damage Assessment (NRDA) processes, it is recommended that the ROD be integrated with the NRDA, to the extent practicable.

In addition to the above objectives, the LWG believes the RI/FS process and resulting ROD will need to provide practical solutions to cleanup while considering other regulatory efforts and a multiuse harbor. Therefore, the LWG has the following general objectives for remedial actions:

1. Promote remedial actions that do not limit current or planned waterway, municipal, commercial, industrial, recreational, or tribal ceremonial uses.
2. Promote remedial actions that are feasible for the physical system of the river.
3. Integrate remedial actions with NRDA findings and restoration plans.

6.3 GENERAL INVESTIGATION APPROACHES

This section defines how the proposed RI work will specifically address selected project issues raised by EPA.

6.3.1 Determine Scope of RI/FS Upstream and Downstream Sampling

EPA and the LWG will work cooperatively to determine the data and analyses needed upstream and downstream of the ISA for EPA to determine site boundaries. A technical memorandum will be submitted that describes the general approach to this issue. This memorandum will be combined with the background approach technical memorandum, described in Section 6.3.2.

6.3.2 Define Background Conditions

Background conditions are typically evaluated to make appropriate risk management decisions, and will be considered in the FS. Evaluation of background conditions will be performed in conjunction with EPA and EPA guidance on this subject (EPA 2002c) and other relevant EPA Superfund guidance. Site-specific background conditions for various data types (e.g., sediment chemistry, fish tissue, sediment toxicity, surface water chemistry) will be identified in the technical memorandum, Approach to Determining Background for the Portland Harbor Superfund Site / Process for Delineating Upstream and Downstream Extent of Contamination. This technical memorandum will describe the definition and approach for determining background levels for the Site. This information will be used, following the risk characterization in the risk assessment, as a risk management tool, consistent with EPA guidelines (EPA 2002c).and. This memorandum will also describe the process for delineating the extent of contamination upstream and downstream of the ISA.

6.3.3 Delineate "Hot Spots"

The overall sampling approach for delineating "hot spots" or principal threat areas involves focusing surface and subsurface sediment sampling in areas where known sources are present and in areas where existing sediment chemistry data indicate elevated concentrations of COIs occur. Round 1 and historical sediment chemistry data will be compared to appropriate sediment screening values for "hot spots," identified in collaboration with EPA and its partners, to identify locations with potentially "high" risk. Additional sediment samples will be placed to better define the extent of the identified areas. The data evaluation process will be repeated with Round 2 sampling results to determine whether new areas can be classified as "hot spots." Additional sampling will be conducted, as necessary, in Round 3 to delineate any "hot spot" areas identified in Round 2.

6.3.4 Define Sediment Management Areas

As discussed in detail in Section 8.6, results from sediment sampling conducted to define the nature and extent of chemical constituents will be combined with baseline risk assessment results, physical environmental data, physical modeling results, habitat data, river and land use data, and source information to define SMAs.

6.3.5 Identify Additional Sources

Existing historical upland information has been reviewed and evaluated to identify suspected historic and ongoing sources; this evaluation will be documented in the updated CSM report. Sediment samples will be located in those areas where existing sediment chemistry data are sparse and historic upland data indicate pathways from suspect sources most likely to impact the river. Sediment transport modeling results and other physical river system data and source information will be used to help locate sediment samples in those areas where sources are expected to impact the river. Also, a limited number of sediment samples will be placed in previously uncharacterized areas that are not associated with any known ongoing or historic sources to reduce uncertainty related to the potential occurrence of impacted sediments from unrecognized or transient historic sources. Each time sediment data are analyzed, the distributions of chemicals will be evaluated to ascertain whether other unrecognized sources may be or may have been present.

6.4 MAJOR PHASES OF WORK

The major tasks of the RI/FS are briefly described below. As noted previously, the intent of this section is to provide an overview of the major milestones to complete the RI/FS, how those milestones relate to each other, and how they fit into overall data collection, evaluation, and RI/FS needs. For clarity, many important smaller tasks are not reflected in this overview, but are discussed in Sections 7 and 8, and Appendices A, B, and C.

6.4.1 Pre-AOC Tasks

Prior to execution of the AOC, a stipulated agreement was signed by the LWG (EPA 2001b) to conduct some significant and time-critical data collection tasks. It was agreed that this information would be necessary for the RI and could be collected prior to Work Plan development. The four tasks listed below were completed under the stipulated agreement:

1. Sediment profile imaging
2. Multibeam bathymetry – high water
3. Juvenile salmonid residence time
4. Integrated evaluation of historical navigation channel bathymetry and a sediment trend analysis.

Of these four tasks, the first three involved fieldwork undertaken by the LWG. The fourth task involved analysis of two pre-existing data sets. Another field effort not included in the stipulated agreement was conducted by the LWG in spring 2002 and involved the collection of water current profiles at 10 transects across the Portland Harbor during a high-flow event (see Section 2.2.3).

These tasks provide fundamental information that is useful in various future RI/FS tasks. In general, they are useful in developing and refining the CSM from physical as well as biological perspectives (see Section 5). An accurate CSM helps define future rounds of sampling and frames needed risk assessment work.

6.4.2 Round 1 Work

Round 1 sampling was conducted in the summer and fall of 2002, and included data collection for clearly apparent needs or exploratory data collection and surveys used to more completely identify future data needs. In addition, the data collection efforts were seasonally dependent tasks, and the LWG did not want to wait another year to initiate them. The LWG prepared a Round 1A FSP (SEA et al. 2002b) for these initial tasks. Round 1A sampling work, approved by EPA in May 2002, included the following activities:

- Collection of fish and shellfish tissue for chemical analysis
- Evaluation of epibenthic colonization using multiplates
- Reconnaissance survey of plants and amphibians
- Reconnaissance survey of adult lamprey
- Measurement of riverbank erosion and accretion using sediment stakes
- Multibeam bathymetry – low water.

A pilot mark/recapture study of juvenile salmonids was also authorized as an additional Round 1A task, but was not completed because the water temperatures were too high by the time the task was authorized, which would have caused unacceptable stress on the fish. Additional sample collection tasks for 2002 were proposed in the Round 1 FSP submitted to EPA in June 2002 (SEA et al. 2002c). A subset of these tasks was approved by EPA in September 2002:

- Beach sediment chemistry
- Reconnaissance-level benthic infauna community analysis
- Collocated sediment chemistry at sculpin, crayfish, and benthic infauna stations.

The LWG also undertook a reconnaissance survey of juvenile lamprey and benthic infauna for potential tissue analysis in September 2002.

Results of each of these sampling tasks will be submitted to EPA either as stand-alone data reports or as part of the Round 1 site characterization summary report that will be provided to EPA within 120 days following completion of Round 1 sampling and analysis.

The data collected in Round 1 meet various RI/FS data needs, including:

- **Fish and Shellfish Tissue and Sediment Chemistry.** Provides critical information for both ecological and human health risk pathways that had little or no pre-existing information. This allows direct measurement of site-specific concentrations to which wildlife and humans may be exposed via fish and shellfish consumption.
- **Multiplates, Reconnaissance Surveys, Benthic Infauna.** Provides information to identify ecological and human health exposure pathways and receptors likely to be present at the Site. This information assists the CSM development and determination of significant pathways and receptors included in the risk assessments.
- **Sediment Stakes and Bathymetry.** Provides time-series data on riverbed changes. These data assist the development of the physical CSM and selection of sampling locations and methods related to issues such as sediment and chemical stability, sedimentation/scour areas, and surface layer depth determination. These data also supplement the STA®, SPI, bathymetric, and other physical system data described in Section 2.

These data will be used in the ecological preliminary risk evaluation report and in both the baseline risk assessment and RI reports. The ecological preliminary risk evaluation report will evaluate and interpret the historic (Category 1), pre-AOC, and Round 1 data (see Section 6.4.3).

In addition to field data collection, existing information is being reviewed during the Round 1 period for the purpose of updating the CSM. Specifically, existing upland site information is being evaluated for potential sources and source-related data as well as data on potential past and/or current pathways to sediment, surface water, and Transition Zone water, from groundwater, storm and wastewater discharges, erosion, and over-water activities.

This information will be used to help categorize potential upland sources of COIs based on the extent to which they have been characterized, their regulatory status, and their potential for affecting sediments or river water. Known or suspected sources will be characterized as:

- Historical, ongoing, or controlled
- Identified and need no further source characterization
- Identified and require further source characterization.

In addition, this process will help identify areas of the river where reviews of historical information indicate the probability of COI sources, but existing information is insufficient to confirm the absence or presence of a source. The information from this review will be evaluated in the context of potential impacts to water and sediments in the river and will be incorporated into updates to the physical and chemical aspects of the CSM presented in this Work Plan.

The results of the information review also will be provided to DEQ so that further upland source identification, characterization, or source control work can be implemented by upland facilities on a site-specific basis.

6.4.3 Additional Project Scoping Activities

Several technical memoranda will be developed to complete project scoping activities that have not been fully documented in this Work Plan, including: 1) Process to Identify COPCs, 2) Derivation of PRGs, and 3) Ecological and Human Health Groundwater Pathways Assessment/Groundwater Sampling Approach. The contents of these technical memoranda are described in Table 6-1:

Technical memoranda also will be completed specifically in support of the ecological risk assessment to more clearly define the scope and methods for ecological risk assessment activities: 1) toxicity reference value (TRV) selection, 2) benthic assessment interpretive approach, 3) comprehensive ERA approach, and 4) food web model. The contents of each technical memorandum also are described in Table 6-1.

An ecological preliminary risk evaluation (PRE) report will be prepared and submitted to EPA and its partners after EPA approval of the TRV technical memorandum. The PRE will include a risk characterization based on historical, pre-AOC, and Round 1 data for benthic invertebrates using the tissue-residue approach, fish, and wildlife. Results will be used, in part, to help identify COPCs related to contaminant concentrations in fish and invertebrate tissue. This applies primarily to risks to aquatic-feeding wildlife that consume fish or invertebrates from the river, and risks to invertebrates and fish containing the compounds. This COPC identification is narrowly focused because sediment data from Round 2 are needed to identify a comprehensive list of COPCs. The PRE will not rely on the benthic assessment technical memorandum, which addresses the analysis framework for the sediment toxicity data to be collected during Round 2. The preliminary risk estimates and the associated uncertainty will help to identify ERA data and information gaps that may be filled during subsequent investigations/evaluations prior to the baseline ERA.

6.4.4 Round 2 Work

Round 2 sampling is intended to gather the majority of the remaining data for the RI and risk assessments as well as initiate the collection of data for the FS. Once Round

2 data are collected, they will be combined with Round 1, pre-AOC, and historic (Category 1) data in a comprehensive site characterization summary to evaluate data gaps and the need for additional sampling efforts. The majority of FS data collection will occur in Round 3. Round 2 is described in more detail in Section 7. It is anticipated that Round 2 will require multiple field efforts. This multiple effort is necessary so that EPA and the LWG have sufficient time to review and agree upon appropriate sampling methods and locations for each type of sampling, and because information needed to develop sampling plans will become available throughout Round 2. For each sampling effort, the procedures will be described in an FSP and approved by EPA prior to initiating that sampling work.

The following data types will be collected during Round 2:

- **Surface Sediment Chemistry**. These data will support the ERA and characterize contaminant distribution and source effects to the river.
- **Sediment Bioassays.** These data will support the assessment of benthic risks for the ERA.
- **Beach Sediment Chemistry**. These data will support the HHRA beach exposure scenario, if needed, based on evaluation of Round 1 results.
- **Surface Water Chemistry.** These data will evaluate potential effects of sources on the river system and support the HHRA and ERA.
- **Physical System.** These additional data, including bathymetry and sediment stake measurements, will be used to define SMAs.
- **Groundwater Impacts from Upland Sources.** Data will be collected to evaluate the impact to sediments and environmental receptors from groundwater chemicals discharging from upland areas to the river
- **Natural Attenuation as a Potential Remedial Alternative**. Limited data will be collected to assess the general feasibility of natural attenuation as a potential remedial alternative, including data collection for natural attenuation model calibration, parameterization, and verification
- **Hydrodynamic/Sedimentation Model.** These data will be used to calibrate, parameterize, and verify models used in the RI.

General types of samples that will be used to evaluate impacts to sediments and environmental receptors from COIs discharging from groundwater include bulk sediment samples and bioassays, Transition Zone water quality samples, groundwater gradient and flux measurements, and surface water (including seep) samples. These types of samples are discussed in more detail in Section 7.

In particular, subsurface sediment sampling will be performed to:

- Define the nature and extent of contaminant releases

- Verify assumptions regarding subsurface stratigraphy used for developing the hydrodynamic model
- Validate the site conceptual model
- Evaluate sediment quality in areas where the hydrodynamic model or bathymetric change assessment indicates sediment scour may occur
- Evaluate sediment quality is areas where potential prop wash, boat wakes, or wind waves may result in erosion of surface sediments and expose underlying sediments
- Evaluate potential dredging or shoreline development areas.

These data collection efforts will provide the basic information needed to refine and validate the CSM, answer questions about the physical system, and identify source effects to the river and the distribution of chemical constituents that may pose unacceptable risks to ecological receptors and human health. Refinement of the CSM will be conducted through examination of data collected during Rounds 1 and 2 to understand the links between chemicals found in various matrices (water, sediments, tissues), the link between sources and chemicals in various matrices, the relationship between physical stability issues and chemical distributions, as well as the relationship between all these parameters and pathways/receptors defined in the preliminary CSM. Where new data indicate the conceptual model was in error or incomplete, the CSM will be revised accordingly. Where new data indicate potential gaps in the understanding of the CSM, additional data collection to fill these data gaps and better define the CSM will be proposed for Round 3 work.

The process for selecting subsurface chemistry sampling locations will be based on information collected in previous rounds or efforts. However, hydrodynamic modeling is an additional task that will be conducted during the course of Round 2 to better understand the physical system of the river. The modeling approach and objectives are detailed in a modeling technical memorandum (West Consultants 2004). This modeling will be confined to understanding river water flows, currents, and resulting sediment transport patterns (e.g., where surface and subsurface sediments are stable over time versus where they are unstable or likely to move or be exposed over time). This model is not intended to predict chemical fate and transport.

Finally, some additional FS-related data evaluations are proposed during Round 2, including a literature review of potential treatment methods and a disposal facility siting evaluation. Conducting these evaluations during Round 2 will allow treatment and disposal alternatives to be considered without delay of the FS process (see Section 6.4.9).

Along with previous rounds of sampling data, the Round 2 information will input directly into the baseline risk assessments discussed in Section 6.4.7.

Based on the results of Round 2 sampling, two reports will be completed in support of the ecological baseline risk assessment: 1) results and interpretation of Round 2 benthic assessment, and 2) food web modeling results. The report on the Round 2 benthic assessment will use the results of Round 2 sediment bioassays to develop and apply a predictive relationship model between chemical concentrations in the sediment and bioassay responses, and confirm toxicity in high priority areas. The food web modeling results report will use data collected in Round 1 and selected results from Round 2 to help develop sediment cleanup goals.

6.4.5 Round 3 Work

The primary purpose of Round 3 work is to gather data for the evaluation of FS alternatives. This work may include collecting some sediment or related data to better define SMAs (and any related principal threat areas). However, in many cases refinement of SMAs may be conducted as part of the RD/RA phase after the ROD. In addition, if there are substantial data gaps identified in the preliminary risk assessments, these may also be filled in some cases during Round 3. As with Round 2, Round 3 may be adapted to one or more sampling efforts, each with an approved FSP, as project developments warrant.

The following data will be collected during Round 3:

- **Surface and Subsurface Sediment Chemistry.** These data will be collected to further refine SMAs and volumes if needed to complete the FS. (In some cases, this information may not be needed to complete the FS, and some areas may be appropriately refined during the RD/RA process that follows the ROD).
- **Surface and Subsurface Physical Characteristics.** These characteristics (e.g., consolidation potential, sheer stress, Atterberg limits, grain size, water content, specific gravity) will be ascertained relevant to potential remedial alternatives.
- **Natural Attenuation Sampling.** This sampling effort (e.g., radioisotope cores, sediment traps, water sampling) will be targeted for areas found in Round 2 to have potential processes that may support this alternative.
- **Potential Disposal Site Sampling**. Sampling at potential disposal sites will be performed, as necessary, to support evaluation of remedial alternatives.
- **Baseline Risk Assessment Data Gaps**. Data will be collected to fill substantial baseline risk assessment data gaps or uncertainties.

- **Uncertainty Analysis**. Data will be collected to fill substantial nature, extent, or source effect uncertainties.
- **Residual Risk Assessment.** Data will be collected to conduct residual risk assessments related to evaluation, comparison, and support of potential remedial alternatives.

These data will be used to prepare the RI and baseline risk assessments and develop the FS. The FS will use the refined SMAs to develop a list of potential remedial alternatives that could be applicable to each area.

6.4.6 Integration of Non-AOC Studies Data

Data from non-AOC studies being conducted in Portland Harbor over the course of the RI/FS will be reviewed for appropriateness following the methods described in Section 4.1.1 and will be incorporated into the project data set as the data become available. Several facility-specific, in-water sampling investigations are ongoing within the ISA. For example, the City of Portland is conducting sediment sampling investigations at its outfalls located in the ISA. Results of the City's outfalls investigations will be made available to the LWG for incorporation into the RI/FS.

6.4.7 Baseline Risk Assessments

At the end of Round 3, two baseline risk assessments will be conducted: one addressing ecological receptors and the other human health. These risk assessments will rely on the information collected through Round 3 and will be presented in the risk assessment reports that will be issued along with the RI report (see Section 6.4.8). The approaches used to conduct these risk assessments are described in more detail in Appendices B and C.

Ecological

The baseline ERA is being designed and performed consistent with EPA (1997, 1998) guidance. ERAs are typically conducted in an iterative or "tiered" manner that increasingly focuses on those exposure scenarios that are the greatest contributors of risk. The risk assessment is complete when the risk managers have enough confidence in the results to make a decision they can scientifically defend (EPA 1998). A tiered process is advantageous because it typically results in refined lists of pathways and receptors that will require application of risk reduction measures. Consistent with this tiered process, the ecological preliminary risk evaluation report will help identify data and information gaps to be filled for a more complete baseline risk assessment.

For both the preliminary ecological risk evaluation and the baseline ERA, the following steps will be completed, consistent with regulatory guidance:

- Describe the results of the problem formulation, including any updates to the CSM.
- Conduct an analysis, including characterization of exposure, characterization of effects, and identification of ecosystem and receptor characteristics.
- Complete the risk characterization, including an estimation of risk, a description of risk, and an evaluation of the uncertainties.
- Communicate the final product to managers and interested parties for risk management decisions.

The risk assessment procedures for each step in this process are detailed in Appendix B.

Human Health

The baseline HHRA will be conducted following Round 3 and will be based on EPA (1989, 1998) guidance. Prior to submittal of the baseline HHRA, a series of interim deliverables will be produced as data become available, these deliverables are described in Table 6-1. Data available at the time of the baseline HHRA will be used to estimate potential human health risks associated with the Site.

Consistent with guidance from EPA (1989) and DEQ (2000c), the baseline HHRA will incorporate the following steps:

- Prepare an analysis plan to identify data needed to adequately assess risks to human health in accordance with state and federal guidance.
- Develop an exposure assessment, which estimates the magnitude and frequency of potential human exposures and the pathways by which humans may be exposed.
- Develop a toxicity assessment, which estimates the probability of adverse health effects that may occur as a result of exposure to a chemical.
- Develop a risk characterization, which estimates the potential for adverse health effects to occur and evaluates the uncertainties associated with the risk estimates.

Following collection of data in Round 3 of the RI, the baseline HHRA will be completed. The results of the HHRA will be used to establish risk-based concentrations that will be protective of human receptors at the Site and to provide input to risk management decisions that address remedial action objectives for the Site. The risk assessment procedures for the HHRA are presented in Section 7 and Appendix C.

6.4.8 Site Characterization Reporting

Validated analytical data will be provided to EPA within 90 days of each sampling activity (e.g., Round 2 surface sediment sampling, Round 2A sediment coring, Round 2B sediment coring, sediment beach sampling, surface water sampling, groundwater pathways sampling). Data will be provided in electronic format showing locations, media, and results. As specified in the AOC, and upon request, analytical data will be made available to EPA within 60 days of each sampling activity.

The following site characterization deliverables will be prepared:

- Field sampling reports
- Site characterization summary reports
- Bioassay data report
- Comprehensive Round 2 site characterization summary and data gaps analysis report
- RI report
- Baseline risk assessment reports.

The contents of each deliverable are described in Table 6-1.

Round 2 and Round 3 information and data evaluations, described above, will be used in combination with Category 1, pre-AOC, and Round 1 data to complete the draft baseline risk assessments (see Section 6.4.7) and an RI report. The baseline risk assessments and RI will include:

- A characterization of the distribution of chemicals and sources that affect the river
- An assessment of ecological risk including risks to benthos, fish, wildlife, and other receptors of concern
- An assessment of human health risks from contact with sediment and water, and fish and shellfish ingestion
- A preliminary delineation of SMAs and sediment volumes that pose unacceptable risks
- A preliminary delineation of principal threat areas
- A preliminary understanding of the potential for natural attenuation as a remedial alternative.

This information will be necessary for the development of remedial alternatives for the FS. Nature, extent, and source characterization results and risk assessment results will be combined with the data and modeling of physical conditions within the river to define preliminary SMAs (i.e., areas that require some type of remedial action) and volumes of sediments that pose unacceptable risks. The delineation of SMAs will consider issues such as:

- Risks for each receptor category (e.g., benthos, wildlife, human health)
- Estimated level of risks (e.g., higher risk areas like principal threats and lower risk areas)
- Types of physical environments relevant to changes in risk and remedial alternatives (e.g., erosive areas, natural attenuation processes, capping)
- Types of river uses that affect remedial alternatives (e.g., navigation channel, slips, docking areas)
- Areas that may be impacted by ongoing sources, upstream or in the ISA.

By integrating these issues, SMAs will define areas that can be used to develop remedial alternatives for the FS. Sediment management areas with relatively high risks will be evaluated for their potential as principal threats. The delineation of SMAs, including areas of “higher” and “lower” risk, is described in more detail in Section 8.6

Following the risk assessment, potential upland and upstream sources will be evaluated for those pathways and COPCs driving risk. Where this information indicates that unacceptable risks may be caused by these ongoing sources, additional source identification and control activities may be warranted.

In the case of potential ongoing upland sources within the ISA, this information will be provided to DEQ so that further upland source identification, characterization, and/or control work can be implemented on a site-specific basis. Given that there is an ongoing DEQ-led effort to identify ongoing sources along the ISA, the LWG does not see the need for extensive independent evaluations of groundwater sources through this RI/FS. However, the LWG will evaluate the in-water impacts of contaminants in groundwater discharging to the river where information gathered by the LWG, DEQ, or other parties indicates the potential for this to occur. The process for focusing the evaluation of potential impacts to sediment, Transition Zone water, and surface water from chemicals in groundwater discharging to the river will be proposed and negotiated with EPA prior to implementation.

Information collected by LWG regarding substantial upstream sources that may influence the risk estimate will be referred to EPA. It is anticipated that EPA review of this information could result in several potential approaches by EPA to identify and control upstream sources, including:

- Identification by EPA of PRPs related to these sources and initiation of site-specific source control efforts through DEQ or EPA-led enforcement with those PRPs
- Identification of another upstream Superfund site or operable units with an appropriate group of new PRPs relevant to that area
- Expansion of the existing Superfund site
- Control of upstream sources by EPA, DEQ, or other agencies through other applicable regulatory mechanisms such as the Clean Water Act, TMDL studies, watershed planning efforts, and NPDES permits.

The information on sources will also be used to assess the potential for recontamination under various remedial alternatives in the FS (see Section 6.4.9).

6.4.9 Feasibility Study Report

The primary purpose of the FS report is to determine appropriate remediation scenarios for sediments that have been shown to pose unacceptable risks through the baseline risk assessments and RI reports. The FS report is discussed in detail in Section 8 and Appendix A. FS-related deliverables are described in Table 6-1. In general, using the information developed from the four rounds of data collection, the FS steps include the following:

- Refine remedial action objectives defined early in the RI/FS process (Appendix A)
- Refine areas and volumes of sediments requiring remediation
- Finalize SMAs
- Develop a range of remedial alternatives that apply to the SMAs in various geographic and physical areas of the river
- Develop a list of remedial alternatives to be evaluated for each SMA
- Conduct a screening and detailed evaluation of those alternatives against the nine CERCLA evaluation criteria
- Conduct a comparative evaluation of those alternatives
- Recommend the most appropriate alternatives for each SMA.

The assessment of remedial alternatives may include evaluations to determine the relative risks posed by each alternative. Depending on the eventual content of the baseline risk assessments, this may include reference to preliminary remedial goals such as sediment chemical concentrations.

In addition to the previous four rounds of data collection already described, several types of data evaluations that support the FS analysis will have been conducted during Round 3:

- Natural attenuation modeling based on Rounds 2 and 3 data collected specifically to assess the potential for natural attenuation
- Refinement, if warranted, of the hydrodynamic/sediment transport model based on Round 2 data inputs
- Recontamination modeling based on source information available through Round 3
- Literature survey to determine the need for treatability studies
- Treatability studies, if necessary, as determined by literature survey
- Disposal facility siting investigations (identifying potential candidate sites for the disposal of contaminated sediments).

These studies will be conducted prior to the actual start of the FS report to ensure that when Round 3 is complete the FS report can be initiated without delay or the need for further data collection or evaluations. Any Early Actions that are proceeding or have been completed under separate agreements with EPA will not be included in the FS report.

Substantial ongoing sources must be controlled before effective sediment remediation can take place. The effects of upland and upstream sources on river sediments and water in the ISA will be addressed by data collection and evaluation efforts (as described above). The FS report will include an assessment of the potential for recontamination for each remedial alternative given current conditions in the river as indicated by data from sampling rounds. This will determine whether effective remediation can proceed without delay given the level and extent of ongoing sources.

7.0 SITE CHARACTERIZATION APPROACH

This section describes the overall technical approach to data collection and analysis for the RI and risk assessments. The approach for the FS is presented in Section 8. Details of sampling and analysis are to be developed with the regulatory agencies based on approval of the framework presented herein, and documented in field sampling plans that will become attachments to this document. Some details of data analysis, such as that for the ecological and human health risk assessments, are presented in appendices and summarized in this section.

A significant amount of information, both quantitative and qualitative, exists for the ISA, yet additional data are needed to support the RI/FS. Historical quantitative data of sufficient quality to support the RI/FS were compiled in the project database and reviewed to identify specific data needs relative to the design of RI/FS field investigations and development of potential remedies. All data classified as Category 1 (see Section 4) were considered appropriate for use as part of the risk assessment process. Both Category 1 and Category 2 data were used for project scoping.

EPA's (2000a) DQO process was applied as part of the historical data evaluation to refine the specific data types needed to complete the RI/FS. The seven-step DQO process is designed to ensure that any data gaps, when filled, will meet the needs of the project. The seven-step DQO process documents the following:

1. Problems or issues that led to the investigation.
2. Decisions to be made or questions to be answered.
3. Inputs (i.e., types and source of data or information) to that decision.
4. Spatial and temporal boundaries of the project.
5. Decision rules or performance criteria used to evaluate the quality of the data and determine the outcome of the decision.
6. Tolerable error relative to the decision rule.
7. A sampling design and analysis plan that will collect the appropriate type and quality of data to meet the project objectives.

The LWG has applied the DQO process and identified a number of field programs needed to complete the RI/FS. The results of this process are described in the remainder of this Work Plan section, and the programs are summarized in Table 7-1. Note that the vast majority of data collected will be used to meet more than one objective of the RI/FS. Additional data needs beyond those shown in Table 7-1 may be identified later in the RI/FS through application of the DQO process.

Table 7-1 also shows the relationship between identified data gaps and the proposed sampling approach. Specific sampling locations will be provided in the Round 2 FSPs.

The following sections describe the issues, questions, decisions, data needs, and RI/FS tasks associated with each data type necessary to understand the physical attributes of the river system and determine chemical distributions, sources, risks and remedies for the ISA, consistent with OSWER Directive 9285.6-08 (EPA 2002b). Data needs that ensue from the DQO process form the basis of the RI/FS sampling program.

7.1 UNDERSTANDING THE PHYSICAL SYSTEM

The physical system of the ISA (e.g., hydrology, sediment movement) will be further investigated as a key element of the RI/FS because it influences the distribution of chemicals as they relate to ecological and human health risk, and finally, any remedial decisions for the Site. This section describes efforts conducted to date and those planned that are designed to gain an understanding of the ISA physical system sufficient to support site characterization efforts, ERA, HHRA, and the FS. A large amount of physical system data has already been collected and evaluated during pre-AOC and Round 1 efforts. A compilation of LWG physical system information is presented in Section 2, and a summary of the physical CSM is provided in Section 5.

The DQO process for understanding the river physical system is summarized in Table 7-2.

7.1.1 Problem Description

The LWR through the ISA is a large river with a complex flow regime and sediment movement patterns. The spatial and temporal scales of sediment movement must be understood at a level that allows accurate characterization of the distribution of chemical constituents, understanding of whether and how ongoing sources are manifested in sediment concentrations, accurate estimates of exposure concentrations for the risk assessments, and an understanding of how sediments move within the system. Hydrodynamic and sediment transport patterns must also be understood to develop and evaluate remedial alternatives for the Site.

7.1.2 Data Uses

Data from the river physical system investigations will be used in conjunction with other data (e.g., chemical distribution in sediment) to determine the following:

- The distribution and magnitude of shoaling and scouring in the ISA as measured directly from time-series bathymetric surveys in Round 1 and Round 2

- The pattern of shoaling and scouring areas in specific bank areas in the ISA as measured directly from sediment stake observations in Round 1 and Round 2
- Sediment movement patterns during major flood years and non-flood years as predicted by the hydrodynamic/sediment transport model.

7.1.3 Data Needs

A third bathymetric was conducted in May 2003 to extend the time series of observed riverbed changes. Also, following a relatively high flow event (about 140,000 cfs) in the LWR in Febraury 2004, a fourth bathymetric survey, including current flow measurements, was performed. The time-series bathymetric change data will be used to calibrate/validate the hydrodynamic/sediment transport model that will be developed as part of the RI physical system investigations (Table 7-2). Low-water and high-flow data (ADCP) from within the ISA were also collected in May 2003 and February 2004, respectively, to support the modeling effort (West Consultants 2004). Surface sediment chemistry, both physical characteristics (e.g., grain-size) and chemical constituent levels, will be collected as part of the Round 2 site characterization program and compared with Round 1 and historic sediment data. These comparisons will be used to support the evaluation of riverbed changes observed or predicted by the physical investigations. Data on regional weather, sediment inflows, river stage, and flows are also needed for the model and are available on public web sites (e.g., USGS, USACE). These data will be compiled as part of the hydrodynamic modeling effort. Finally, additional data needs (e.g., site-specific critical erosion velocities, suspended sediment loads) may be identified during model development following Round 2 that are needed to refine or improve model accuracy. These data would be collected as part of Round 3.

7.1.4 RI/FS Tasks

Physical system investigations completed as part of pre-AOC RI/FS studies or during Round 1 include a compilation of previously existing information and the following efforts:

- Integration of the Sediment Trend Analysis (STA®) (GeoSea Consulting 2001) survey data from Portland Harbor (September 2000), with an evaluation of historical changes in navigation channel depths based on Corps hydrosurvey data
- Sediment-profile imaging survey of the LWR from RM 0 to 15.7 in December 2001 (SEA 2002f)
- Precision multibeam bathymetric surveys from RM 0 to 15.7 in winter 2001 and the summer of 2002 (DEA 2002a, 2003)

- ADCP current profiling during a high-river stage event on April 19, 2002
- Deployment and monitoring of sediment stakes.

The preliminary physical CSM model based on these surveys and data evaluations is provided in Section 5.

Physical investigations also have included a third bathymetric survey of the Portland Harbor and a short-term ADCP survey during a low-water/high-tidal influence period conducted in the spring of 2003 and a fourth bathymetric and ADCP survey during and immediately following a high flow event on the Lower Willamette in February 2004. The development, calibration, and validation of a hydrodynamic/sediment transport model of the LWR are planned in Round 2. If the hydrodynamic modeling process identifies other physical system data needs (e.g., site-specific erodibility measurements), these data will be collected late in Round 2 or in Round 3.

Hydrodynamic Modeling: The proposed modeling approach is fully detailed in the revised technical memorandum submitted to EPA in February 2004 (West Consultants 2004). As stated in the technical memo, the objectives of the modeling effort are to:

- Determine the spatial and temporal sediment transport patterns so that surface contaminant distributions and risks to ecological and human receptors in the Lower Willamette River can be adequately characterized.
- Determine whether physical processes expose previously buried contaminated sediment, including during major flood events.
- Determine whether physical processes result in burial of contaminated sediment.
- Quantify the rates and locations of sediment accretion and erosion associated with various flows, including extreme events.

The model is designed to provide both an assessment of more short-term or “typical” sediment transport regimes in the river and estimates of flow velocities and sediment transport under rare high-flow events. Along with grain size, bathymetry, sediment stake, and flow data, the modeling will help identify sediment transport regimes within the river, such as depositional, erosional, and transitional areas. This information will be valuable in understanding the existing distribution of chemicals, as well as potential source transport, recontamination, and natural attenuation issues. The modeling of high flow events will identify potential scour areas that might expose subsurface contaminated sediments in extreme high flows and will predict design parameters, such as bed velocities, that are required to evaluate remedial alternatives (e.g., capping or confined aquatic disposal).

Pending approval by EPA of the proposed modeling approach in early 2004, the initial modeling effort will be completed in the summer/fall of 2004. Sediment and other data collected in 2004 will be used to refine the model in 2005. As warranted, the model results will be used to focus Round 3 data collections, e.g., indicating a need for additional subsurface sediment data in an unstable area. Also, any data gaps identified by the modelers as critical to model performance will be targeted for collection as part of Round 3. Table 7-2 provides additional details on how the modeling effort fits into the physical system investigations and how model output will be used to support the RI/FS.

7.2 UNDERSTANDING CHEMICAL DISTRIBUTIONS AND SOURCES

As part of a comprehensive CSM, it is critical to identify potential sources and the distribution of chemicals resulting from those sources. In the ISA, the sediment itself may act as a source. There may also be surface water and groundwater inputs to the system, in addition to the other sources presented in Sections 3 and 5. These potential sources and the process for understanding the distribution of chemicals related to these sources are discussed below.

To understand the distributions of chemicals, a list of chemicals was developed for the Round 1 sampling program based on historic data, current and historic activities, and laboratory reporting capabilities. The initial list of chemicals, which is included in the EPA-approved Round 1 QAPP (SEA 2002e), may be revised in later rounds of investigation (e.g., following EPA approval of the Round 2 QAPP). The process that will be used to limit chemicals from future investigations through identification of COPCs will be submitted to EPA as a technical memorandum.

7.2.1 Sediment

Sediment samples will be collected to identify potential sources, understand the distribution of chemicals resulting in potentially unacceptable ecological and human health risks (described in Sections 7.3 and 7.4), and to evaluate natural attenuation for the FS (described in Section 8). A systematic and iterative approach will be used, as described below, for implementation of sediment sampling events. This approach will allow identification of any significant new sediment sources and characterization of the nature and extent of sediment contamination associated with existing sources, as needed for risk and remedial alternative evaluations.

The DQO process for understanding chemical distributions in sediments and sources is summarized in Table 7-3.

Problem Description

Although there is a considerable amount of historical sediment data for Portland Harbor, additional data are needed to generally describe areas that pose unacceptable risk (i.e., SMAs). Additionally, surface and subsurface sediments may act as sources to other parts of the Portland Harbor.

Data Uses

Data from the sediment investigation will be used in conjunction with Category 1 historical data to:

- Characterize the distribution of chemical constituents in surface sediments in potential exposure areas
- Characterize the distribution of chemical constituents in subsurface sediments that have the potential to act as sources or that are located in potential remediation or navigation/maintenance dredge areas
- Characterize the potential inputs from upland sources to the ISA
- Complete the baseline risk assessments
- Complete the FS.

Data Needs

Sediment chemistry data are needed for chemicals and conventional parameters listed in the QAPP. Sampling and analytical methods will be adequate to achieve analytical concentration goals listed in the QAPP, when feasible (i.e., analytical concentration goals, which are developed based on risk screening, may be below the concentrations that can be achieved using available analytical instrumentation, especially in samples with matrix interferences). Surface sediment data are required to understand the distribution of chemicals resulting in potentially unacceptable risk; subsurface sediment data are required in areas where subsurface chemicals may act as potential sources including near some historic sources, in navigation/maintenance dredge areas, and in berthing site areas that may scour. Finally, subsurface data will be used in the FS to assess sediment volumes in SMAs requiring cleanup.

RI/FS Tasks

Phasing of Sediment Investigations

The generation of sediment data to support the RI/FS will follow an iterative process. Sediment sampling was conducted in Round 1 and will be conducted in Rounds 2 and 3 of the RI/FS. Composite samples were collected in Round 1 at numerous beaches to evaluate potential human health risks to beach users. To support the ERA, additional Round 1 sediment samples were collected at selected locations where sculpin, crayfish, clams, and other benthic infauna were found, and in selected potential wildlife exposure areas. Clams and other benthic infauna were not collected at most stations in Round 1 because they were not found in these locations at sufficient volumes for the entire list of analytes. More tissue and/or sediment may be needed based on the results of the preliminary ecological risk evaluation.

Round 2 sampling is envisioned to include multiple sampling efforts, including the collection of surface sediments to aid the understanding of sources and to support the ERA. Concurrent bioassay testing will occur in Round 2 at a significant number of these stations to support the benthic assessment for the ERA. Round 2 also will involve collection of subsurface cores to evaluate subsurface distributions of chemicals in areas where those sediments could act as sources and in navigation or maintenance dredge areas. Identification of actual core locations will occur in the various Round 2 FSPs. Hydrodynamic modeling and bathymetry survey results will help focus the subsurface sampling locations on areas of potential scour. Round 2 will include a limited number of subsurface cores to assess the potential presence of natural attenuation processes in the ISA.

Round 3 sediment sampling is intended to support the FS (see Section 8). However, data gaps related to uncertainties in the preliminary risk assessments and/or sources could be filled in Round 3 should this information be needed to make a risk management decision.

Surface Sediments Approach

In addition to the objectives presented in Section 6.4.3, a number of factors will be considered when selecting surface sampling locations:

- **Proximity to Sources.** Sediment sample locations will be placed near known and suspected historic and ongoing sources, including seeps, outfalls, utility crossings, and potential groundwater discharge areas. The intent of such sampling is to understand the effect of any such sources on sediments in the river.
- **Proximity to Overwater Structures.** Sediment sample locations will be placed near product transfer points (fuels and solid products) and docks to better understand these potential sources.
- **Previously Uncharacterized Areas.** Where there are exposure areas with little historic data, additional samples will be located to better understand the distribution of chemicals that may pose unacceptable risk or act as sources.
- **Nearshore Areas.** Sediment sample locations will be placed in previously uncharacterized nearshore areas because of the proximity of sources and the higher value of this habitat to biological resources. As evident from the maps provided and

discussed in Section 4, chemical concentrations tend to be highest in nearshore areas.

- **Sediment Transport.** Sediment sample locations will be placed in accreting areas rather than erosional areas. However, some sampling may occur in erosional areas to help understand the effects of erosion on chemical concentrations in these areas.

Sampling locations and methods will be presented in the FSP(s). The depth of sampling will be 1 foot, which is based on evaluation of bathymetric changes between December 2001 and August 2002 (DEA 2003) and potential ecological and human health exposure areas. Chemical analysis of surface sediments will follow the Round 2 QAPP until such time when a reduced list of COPCs may be available. Certain analyte groups will only be analyzed under specific conditions, including:

- VOCs will be analyzed where available groundwater data suggest that VOCs may be reaching the river.
- Butyltins will be analyzed offshore from ship repair/maintenance and storage facilities that were in operation after the introduction of TBT as an antifoulant.
- Dioxins and furans will be analyzed offshore from potential source areas and at a small number of stations distributed throughout the ISA.

Fish tissue analytical results may also be used to identify areas where these additional analyte groups will be analyzed.

Subsurface Sediments Approach

Subsurface sediment sampling will occur over two primary sampling events, with different objectives for each event. In Round 2, subsurface data will be generated to support the evaluation of potential sources and the presence of natural attenuation processes. The approach for and reasoning behind natural attenuation sampling is detailed in Section 8 and Appendix A. In Round 3, subsurface data will be generated to support the FS.

In a dynamic riverine system such as the LWR, sediments are eroding and accreting along variable spatial and temporal scales. It will be important in this system to evaluate subsurface sediment chemistry in areas that have the potential for erosion to cause buried sediments to become surface sediments and therefore potential sources.

The bathymetric surveys already completed by the LWG (DEA 2002a, 2003) demonstrate that typical erosional and depositional forces may result in changes to sediment elevations that can be on the order of a few feet in some places, although in most areas the river bed elevation changes were less than or equal to one foot. These surveys were conducted during a year that was characterized by relatively typical flows for the last decade. In periods of higher flows and during flood events, there may exist a greater chance for sediment scour and re-deposition. Therefore, it is important to evaluate the chemistry of buried sediments in areas that may be scoured during extreme flow events.

Results from the hydrodynamic/sedimentation modeling that is being undertaken by the LWG will be available 120 days after EPA approval of the modeling approach technical memorandum. Based on modeling results, additional core locations may be identified as data gaps for Round 3 sampling (see Table 7-2).

Berthing areas are often associated with scour due to prop wash and are often dredged for navigation purposes. Review of either the 2001 or 2002 bathymetric maps (DEA 2002a, 2003) shows likely areas of prop-wash-induced sediment scour off several facilities. Again, it will be important to evaluate sediment chemistry in known or historic source areas that have the potential for erosion (e.g., from prop wash) and/or areas of potential navigational dredging that could cause buried sediments to become surface sediments.

Following the preliminary risk assessments, the LWG will identify SMAs that will contain areas that pose an unacceptable risk. If dredging is a reasonable remedial alternative for one or more of the SMAs, then additional subsurface chemical data may need to be collected during Round 3 and the RD/RA to refine the depth to which contamination extends and collect information on sediment engineering properties. Similarly, if natural attenuation is to be considered for an SMA, then appropriate subsurface sediment data will be collected in Round 3 to determine the efficacy of site-specific natural attenuation processes. SMA-specific information on sediments may also be needed for other alternatives such as capping or aquatic disposal, including additional surface/subsurface chemical and/or physical data.

7.2.2 Surface Water

Surface water samples will be collected to identify potential sources, to understand the distribution of chemicals resulting in potentially unacceptable ecological and human health risk (described in Sections 7.3 and 7.4), and to understand the potential for recontamination for the FS (described in Section 8).

The DQO process for understanding the distribution of chemicals in surface water is summarized in Table 7-4.

Problem Description

There is little existing water quality data for the ISA. Therefore, the objectives of the water sampling program are to assess water quality conditions in the ISA under different flow conditions, provide water quality data for use in the ecological and human health risk assessments, and provide water quality data for the assessment of recontamination potential during the FS.

Data Uses

Surface water data will be used to determine:

- If upland sources in the ISA are contributing to unacceptable risk from river water
- Support for the ecological and human health risk assessments
- If various river stages and flows and storm events have a measurable effect on the nature or concentration of surface water chemical constituents
- The impact to the ISA of potential upstream sources of surface water chemical constituents
- The potential presence of natural attenuation processes within the ISA
- The potential for recontamination of remedial alternatives (examined in the FS).

Data Needs

Sampling and analytical methods must be adequate to achieve detection limits that are below risk-based water quality screening levels. Sampling will be conducted during an early fall "first flush" stormwater runoff event and both low-flow and high-flow river conditions. Sample location and density must be adequate to assess variation in chemical concentrations in surface water immediately upstream, downstream, and within the ISA. Sample location and density must also be adequate to understand the potential for source effects to river water and sediments.

RI/FS Tasks

A tiered approach to the water quality investigation is proposed. Surface water sampling was proposed by the LWG but not approved by EPA in Round 1. In Round 2, surface water samples will be collected using high-volume sampling methods at three transects: one transect at RM 11 above the upstream boundary of the ISA, one transect at RM 6.3 within the ISA, and one transect at RM 4 at the lower boundary of the ISA. Upstream samples will be used to evaluate the upstream contribution of chemicals to the ISA. High-volume samples also will be collected at four locations (Rhone Poulenc, Willamette Cove, ATOFINA, and Portland Shipyard) during an optimum-flow sampling event to assess potential source effects. Grab samples will be collected to support the ERA. Grab samples will also be collected in potential swimming areas to support the HHRA.

Specific Round 2 water quality sample locations, analyses, collection methods, and required analytical detection limits will be provided in the Round 2 surface water sampling FSP. High-volume surface water sampling methods will achieve minimum reporting limits below chronic and acute Ambient Water Quality Criteria (AWQC) and Oak Ridge National Laboratory ecological screening values and below AWQC for the protection of human health and EPA Region 9 PRGs. Grab sampling methods will achieve minimum reporting limits below chronic and acute AWQC and Oak Ridge National Laboratory ecological screening values and below EPA Region 9 PRGs for all COPCs except N-nitrosodimethylamine, toxaphene, and dioxins/furans. These criteria are used to identify analytical reporting limits and for screening purposes.

Additional surface water samples will be collected in Round 3 for analysis of persistent, bioaccumulative toxins (PBTs) using high-volume sampling methods if a data gaps analysis based on Round 2 sampling results, the ecological preliminary risk evaluation, food web modeling results, and groundwater impacts evaluation scoping determines that additional surface water data with very low minimum reporting limits are needed to develop PRGs or evaluate source effects. Similarly, if additional surface water sampling to determine chemical distributions, source effects, natural attenuation, or recontamination potential is necessary, the proposed approach will be presented in a Round 3 FSP.

7.2.3 Groundwater

Table 7-5 summarizes the DQO process for understanding the hydrogeologic physical system and the effects of groundwater discharges on ecological and human health risks and the distribution of chemicals in sediment.

Problem Description

In the physical conceptual site model (see Figure 5-1), groundwater flow is identified as a possible pathway between upland sites and the Willamette River. COIs are present in groundwater underlying a number of upland sites along the ISA. Because the river is a primary discharge point for the groundwater from the upland sites, it is important to determine whether these COIs can migrate to the Willamette River at concentrations that pose a potential human health or ecological risk. In addition, it is important to consider the total loadings of persistent, bioaccumulative toxins (PBTs) to the river.

Among the media investigated in the RI/FS, groundwater is unique because of the regulatory framework established by the memorandum of understanding (MOU) between EPA and DEQ (EPA et al. 2001). For purposes of the RI/FS, upland releases are assumed to be the source of contaminated groundwater. According to the MOU, DEQ has lead authority for investigating upland releases and, if necessary, requiring source control measures to protect sediment and water quality in the Willamette River against the threat of ongoing contamination from such releases. The purpose of DEQ investigation and source control measures is to identify and eliminate ongoing upland sources of contaminated groundwater that are contributing, or threaten to contribute, contaminants to the ISA.

Because of its focus on risk in the Willamette River, the groundwater component of the RI/FS will ultimately concentrate on evaluating the risks to human and ecological receptors from contact with groundwater contaminants that have been transported to the Transition Zone (including sediment and water) or surface water through seeps within the Site. The groundwater component of the RI/FS should consider the risk presented from the cumulative effects of PBTs entering the river and subsequent bioaccumulation in fish. To accomplish this, information on known groundwater sources impinging on the river is needed to identify chemical contaminants and potential exposure points in the river. In addition, information is needed to identify areas where groundwater contamination is possibly affecting the river, but cannot be confirmed with existing upland or in-water information. Under the Source Control Strategy, DEQ and EPA will implement a formal screening process to identify sites where groundwater COIs may result in unacceptable risks in the river. The combined upland investigations and Source Control Strategy processes provide a high degree of confidence that most of the sites where contaminated groundwater may adversely affect the Site are identified for consideration in the RI/FS.

As part of DEQ's ongoing Cleanup Program, DEQ has overseen or conducted extensive investigations of groundwater at upland sites adjacent to the ISA. The resulting data provides a basis for evaluating the effects of contaminated groundwater on risk in the river. However, additional information will be necessary to evaluate areas where data are insufficient to determine the need for further analysis. (Identification of such areas and the associated data needs are addressed in following sections.) Once groundwater contamination has reached the river, the receptors potentially most affected are benthic-dwelling fish and invertebrates. Human exposure may also occur through dermal contact with groundwater emerging as seeps in beach areas. In addition, contaminated groundwater discharging to areas of relatively isolated or quiescent waters may affect surface water quality and result in exposure to fish and/or amphibians. Humans and higher trophic-level ecological receptors could also be indirectly affected if groundwater COIs sorb to sediments, disperse in surface water to unacceptable levels, or bioaccumulate in prey items.

The potential for groundwater contaminants to affect ecological risk in sediments is highly dependent on the characteristics of the contaminants being introduced to the sediment. Groundwater contaminants with low water solubility and high soil/sediment adsorption coefficients will preferentially sorb to sediment particles, and only a small fraction will partition from sediment to the aqueous phase. Metals and hydrophobic organic contaminants typically have low mobility and high sediment sorption characteristics. For these chemicals, the aqueous concentration in the Transition Zone is controlled by the rate at which the chemical desorbs or dissociates from the solid phases and becomes available in Transition Zone water to benthic infauna. Toxicity and risk of such chemicals to ecological receptors can be assessed through chemical analysis or toxicity testing of bulk sediment samples from locations where the chemicals in groundwater are discharging to the Transition Zone.

Groundwater contaminants with high water solubility and low soil/sediment adsorption coefficients may not sorb to sediment, but may affect aqueous concentrations as contaminated groundwater moves into the Transition Zone. Other factors, such as organic carbon content of the sediment, volatility and degradation of the groundwater contaminant(s), and co-solvency mechanisms, will also affect the fate and transport of groundwater contaminants through the Transition Zone. Concentration of such chemicals in Transition Zone water is more likely to be dependent on the concentration in groundwater entering the Transition Zone and the extent to which it mixes with water from other sources. Such chemicals may not be identified in bulk sediment samples, and separate sampling methods may be necessary to estimate exposure where such contamination may occur and present a risk to identified ecological receptors, which are expected to be primarily benthic organisms.

Data Uses

The overall objective of the groundwater evaluation is to assess whether contaminated groundwater discharging to the ISA causes unacceptable risks to ecological and potential human receptors. Consequently, the groundwater evaluation process is integrated with the ERA and HHRA. Data collected to evaluate the impact of contaminated groundwater discharging to the ISA will be used to:

- Identify the locations and extent of contaminated groundwater impacts and the COI concentrations or measured toxicity of the potential impacts in the ERA
- Identify potential human exposures to COIs in groundwater seeps and to assess human health risks from that exposure in the HHRA
- Determine SMAs (see Section 6) within the Site
- Identify preliminary remedial actions.

The overall approach adopted by the LWG for evaluating effects of groundwater contaminants on sediments is consistent with the tiered approach for groundwater/surface water assessments recommended by EPA (2000b). The approach requires repeated integration of the site characterization and ERA tasks of the RI/FS.

Data Needs

Data needs for evaluating the potential impacts from groundwater contaminant discharge to the river are location-specific, and thus will be determined site-by-site based on the type of COIs present in groundwater as well as the existing understanding of groundwater flow and discharge. Data needs for the groundwater evaluation will be assessed by:

1. Compiling and evaluating existing data from DEQ files and published literature on the physical hydrogeologic system and upland contaminated groundwater distributions to identify where groundwater contamination is confirmed or has a reasonable potential to discharge to the ISA and identifying the COIs for these discharges
2. Developing an understanding of the physical relationship between groundwater and surface water within the ISA and the influence of the hydrogeological physical system on exposure pathways in the ISA
3. Refining and updating the hydrogeological CSM
4. Developing a process for assessing and focusing the areas for further evaluation and identifying the types of samples for addressing the data needs.

The updated CSM report will provide the results of the compilation and evaluation of groundwater physical system and groundwater quality data and a discussion of the influence of the hydrogeological physical system on exposure pathways in the ISA. The CSM will be augmented as additional information is gained through RI characterization tasks. The process for focusing the evaluation of potential impacts to sediment, the Transition Zone, seeps, and surface water from chemicals in groundwater discharging to the river, as described later in this section, will be negotiated with EPA prior to implementation.

If data needs are identified for characterizing potential impacts to receptors from groundwater discharging to the river, the LWG in cooperation with EPA will assess the need for additional data collection. The types of data needed to evaluate the potential for effects of exposure of receptors to groundwater discharges to the river or human use areas will vary on a site-by-site basis and may include one or more of the following:

- Chemistry of bulk sediment samples
- Chemistry of water samples obtained from the Transition Zone
- Chemistry of seep samples in human use areas
- Chemistry of surface water samples in quiescent areas
- Groundwater flow measurements
- Toxicity testing to support the ERA.

The activities and tasks for evaluating the potential impacts will be described in separate field sampling plans for individual sampling events.

RI/FS Tasks

As with other aspects of the RI/FS, the groundwater evaluation involves integrating data needs for characterizing chemical distributions in the river with those of the ERA and HHRA, on which risk characterization decisions will be made. The proposed RI/FS tasks associated with groundwater are:

Task 1: Groundwater Data Review and CSM Update,

Task 2: Process for Assessing and Focusing Data Needs,

Task 3: Data Collection.

A description of each of these tasks is provided below.

Task 1. Groundwater Data Review and CSM Update

The objective of this initial task is to use the data compiled during the groundwater data review to update the hydrogeological CSM for the site. Specifically, the updated CSM will reflect the results of the groundwater data review and will include the following information:

- Description of the physical hydrogeologic framework, groundwater flow systems, and surface water/groundwater interactions
- Categorization of upland sites based on availability of groundwater chemistry data, presence of groundwater containing COIs, and presence of complete or likely complete exposure pathways to receptors in the river.

The existing hydrogeologic data compiled during the groundwater data review will be used to understand the following specific attributes of the physical hydrogeologic system:

- The nature and location of groundwater discharges
- Spatial relationship between hydrostratigraphic units and the river
- Spatial and temporal changes in groundwater flow and river stages.

The groundwater data will also be used to categorize the upland sites within the ISA based on available groundwater chemistry information, as follows: 1) sites where groundwater containing COIs are known or suspected to discharge to the river, 2) sites where COIs are present in groundwater but where upland data are insufficient to assess the potential for COIs to reach the river, and 3) sites where groundwater data are not available.

Upland sites where groundwater containing COIs are known or suspected to discharge to the river will be categorized based on the following factors:

- Known past or present releases of NAPL or aqueous-phase concentrations of COIs

- Frequent detections or high concentrations of COIs in groundwater samples collected adjacent to the riverbank
- High concentrations of COIs or NAPL in groundwater that intersects human-made or natural preferential pathways that potentially discharge to the river
- High concentrations of COIs or NAPL that are not adjacent to the river bank or do not intersect preferential pathways but COIs still have the potential to reach river sediments
- Presence of a complete exposure pathway between groundwater and receptors in the river.

Sites where COIs are present in groundwater but where available upland data are insufficient to assess the potential for COIs to reach the river will be referred to DEQ to address per the Source Control Strategy. Sites for which groundwater data are not available will be assessed using historical land use information, including historical aerial photographs and Sanborn maps, as available, to identify sites where there is a reasonable possibility for impacts to groundwater based on historical site uses. For these sites, available information will be summarized and recommendations made to DEQ for site assessment purposes. For sites where groundwater data gaps have been identified and where groundwater data are not available through the groundwater data review process and cannot be readily obtained for a particular site based on the RI/FS schedule, the LWG will evaluate the potential groundwater impacts to the river on a site-by-site basis and will implement a process for assessing data needs and potential data collection activities, as described under Tasks 2 and 3 below.

The physical hydrogeologic data and information on COIs in groundwater will be integrated with the information collected during the October 2002 seep reconnaissance survey (GSI 2003b) to refine the hydrogeologic CSM (Section 5.1). The CSM will continue to be updated following incorporation of data collected during subsequent RI/FS characterization activities.

Task 2. Process for Assessing and Focusing Data Needs

The objective of this task is to identify and focus areas where potential effects of chemicals in groundwater discharging to the river need further evaluation. The process for assessing and focusing these data needs will be developed in cooperation with EPA prior to implementation. It is anticipated that the areas requiring additional data and the types of data collection necessary to achieve this objective will vary between locations depending upon COIs and other site-specific data needs.

The process for assessing and focusing data needs will be based on the following information:

- Location(s) and geometry of upland groundwater COI plumes

- Horizontal and vertical groundwater gradients (groundwater flow direction) at the upland sites of interest
- Upland hydrostratigraphic information
- Locations where the groundwater pathways to receptors in the river have been identified as complete
- A survey to identify the locations of focused groundwater discharge
- A conservative contaminant screening step.

The first three sources of data information listed above will be evaluated and summarized as part of the updated CSM document. This information will be integrated with the groundwater discharge survey data and the contaminant screening to identify appropriate areas offshore of upland sites where groundwater COIs have a reasonable potential to reach the river. Also, the groundwater discharge survey data and the contaminant screening assessments, as described below, will be conducted iteratively to better focus the sampling effort on areas where there is a potential for impacts to receptors from groundwater discharging to the river.

Pilot studies may be conducted to evaluate the scope of RI groundwater sampling efforts and to evaluate sampling methodologies. If the pilot studies are deemed prudent, the details will be developed in cooperation with EPA in a technical memorandum prior to initiating any field work.

Groundwater Discharge Survey Assessment

The data needs assessment process will identify locations of groundwater discharge that should be further evaluated. The steps that will be used to identify these locations and the methodology for the assessment will include the following:

1. Evaluate the feasibility of utilizing survey tools (e.g., towed probes) to identify groundwater discharge areas on a site-specific basis.
2. Where feasible, use groundwater flow direction, plume location and geometry, and available stratigraphic information to guide a site-specific groundwater discharge survey at sites identified in Task 1 and through the contaminant screening assessment by using the appropriate techniques, such as forward-looking infra-red (FLIR) or towed probes.
3. Interpret the results in the context of the upland information.
4. Where use of survey techniques is not feasible, use groundwater flow direction, plume location and geometry, available stratigraphic information, the results of the contaminant screening,

and, if necessary based on consultations with EPA, other survey techniques such as an in-water stratigraphic survey to identify possible discharge areas.

5. Integrate information with the CSM and contaminant screening assessment to identify areas where groundwater discharge should be assessed using survey methods.

Contaminant Screening Assessment
The data needs process will also evaluate the potential for impacts to ecological and human receptors through a conservative screening level assessment. As stated above, the combined results of the screening step together with the information from the CSM and the groundwater discharge survey data will be used to focus the groundwater data collection task on areas where groundwater COIs have a reasonable potential to reach the river. The details of the screening approach to focus the evaluation of the exposure of ecological and human receptors to chemicals transported in groundwater discharging to the river will be proposed and negotiated with EPA prior to implementation. It is expected that sites where concentrations of COIs in groundwater do not or are not likely to reach the Transition Zone at concentrations that exceed conservative screening criteria (e.g., AWQCs) will not require additional sampling.

Ecological Screening Approach
Data needs for evaluating potential impacts to ecological receptors will be identified based on the results of prior tasks and an evaluation of COI characteristics. For locations where COI concentrations exceed screening criteria, chemical characteristics of the COIs will be evaluated for their preference to sorb to sediments. Criteria, including octanol-water partitioning coefficients (K_{ow}), organic carbon partitioning coefficients (K_{oc}), or soil/water partitioning coefficients (K_d), will be used in this analysis. In addition, physical characteristics of sediments and the types of contaminants that are present will also be considered to help determine appropriate media to be sampled.

Locations with COIs that preferentially sorb to sediments will be evaluated using bulk sediment samples and standard risk approaches for assessing effects to benthos. Locations with COIs that preferentially partition to the aqueous phase may be subjected to alternative sampling and analyses for characterizing exposure and risk, such as sampling of Transition Zone water and/or surface water sampling in quiescent areas. The type of sampling and analysis will include techniques that could be used for estimating exposure point concentrations. As noted previously, the types and quantity of sampling will be site-specific.

The details of the screening process, including the types of data to be screened and the screening-level values, will be discussed with EPA prior to implementation. Upon EPA approval, the proposed processes will be integrated into the ERA approach and documented in a technical memorandum that will become part of the RI/FS Work Plan.

The results of this analysis and data collected during Round 2 and Round 3 of the RI will be incorporated into the ERA approach for benthic organisms and, if applicable, other receptors. The specific processes for risk analysis are detailed in the ERA approach (Appendix B).

Human Health Screening Approach
Data needs for assessing potential impacts to human receptors from COIs in groundwater discharging to the river will be evaluated using the results from the groundwater data review and seep reconnaissance survey through the following steps:

1. Compare upland sites identified in Task 1 (groundwater data review and conceptual model) that have a potential for COIs to discharge in groundwater with the identified seeps in potential human use areas. This comparison will assess whether any of the sites are located upgradient from the seeps where direct human contact could occur.
2. After the evaluation described above is completed, the LWG, in consultation with EPA and its partners, will determine which seeps will need further evaluation for human health risk assessment and the methods that will be used for this evaluation. This evaluation may include assessment of existing groundwater data or of new data collected by the LWG or other parties.

Seeps will be sampled to determine exposure point concentrations at human use areas where the exposure pathway for groundwater COIs is complete and may result in a risk to human receptors. Details of how risks from these pathways will be incorporated into the HHRA are described in the HHRA approach (Appendix C).

Task 3. Data Collection

Based on the results of the process for assessing and focusing data needs (Task 2), a sampling program will be designed to address data gaps where there is potential for groundwater impacts to human or ecological receptors. Details on the specific activities and sample locations will be described in separate FSPs submitted to EPA prior to implementation. It is expected that this data collection effort will occur during Round 2 and possibly in Round 3, if deemed necessary.

Based on current knowledge of the groundwater data, potential data collection efforts may include one or more of the following:

- Chemistry of bulk sediment samples for COIs that sorb to sediments at locations where concentrations exceed screening criteria, and where data gaps have been identified and groundwater data adequate for assessing potential impacts to the river cannot be obtained in a timely fashion based on the schedule for the RI/FS

- Chemistry of samples of water in the Transition Zone for COIs that may not sorb to sediments at locations where concentrations exceed screening criteria, and where data gaps have been identified and groundwater data adequate for assessing potential impacts to the river cannot be obtained in a timely fashion based on the schedule for the RI/FS
- Chemistry of seep samples in human use areas.
- Chemistry of surface water samples in quiescent areas
- Groundwater flow measurements, where groundwater data adequate for assessing potential impacts to the river cannot be obtained in a timely fashion based on the schedule for the RI/FS
- Toxicity testing (as necessary for the ERA).

The potential effects of exposure of ecological receptors to groundwater discharging to the Transition Zone will be evaluated through sampling of sediment and water within the Transition Zone. Sediment and water sampling within the Transition Zone will be considered at potential groundwater discharge locations where groundwater COIs are confirmed to discharge or have a reasonable likelihood to reach the Transition Zone within the river. Sample density will be sufficient in the vicinity of these discharge areas to allow representative characterization of groundwater that poses a potential risk to biota.

The potential effects of exposure of humans to groundwater discharging in surface seeps will be assessed based on seep sample chemistry in defined human use areas. The effects of exposure of biota to groundwater discharges in quiescent areas will be evaluated through surface water sampling in such areas. Potential risks to human or ecological receptors associated with possible indirect exposure to COIs in groundwater will be evaluated using sediment, surface water, and tissue data.

Coordination of surface water and in-water groundwater data collection will be important at locations where groundwater COIs are assessed in order to understand potential relationships between chemicals detected in groundwater and surface water quality while reducing possible temporal variability.

Assessment of the potential effects on receptors and surface water of certain COIs transported in groundwater to the Transition Zone and surface water may require an integrated sampling approach involving both measurement of physical groundwater flow parameters and chemical sampling in the river. The types of data and techniques for obtaining the data are discussed in the following sections.

Physical Groundwater Data
Physical groundwater flow data may include measurement of groundwater flow direction and groundwater flux rates depending on the data needs for a particular location. The direction of groundwater flow adjacent to and in the river may be important for assessing the location and extent of the area where chemicals in groundwater may discharge to the Transition Zone and surface water. Groundwater flow information from individual sites will be used for assessing physical hydrogeological conditions in the Transition Zone where available and adequate. In areas where site-specific data are not available, groundwater flow proximate to the river is assumed to be directly towards the river or at perpendicular flow patterns to the river. Measurement of hydraulic head using nested mini-piezometers can be used, as necessary, where an understanding of vertical groundwater gradients is needed.

To assess risk and recontamination potential, knowledge of groundwater flux may be important for understanding local or overall contaminant flux and loading from a COI plume. The general rate of groundwater flux can be calculated from the hydraulic gradient and hydraulic conductivity measurements where these data are available from upland sites. When these data cannot be estimated from existing information, the groundwater flux rate in a localized area can be measured using seepage chambers.

Chemical Groundwater Data
The techniques used to collect water chemistry data from the Transition Zone or groundwater depend on the uses of the data and types of contaminants targeted. The sampling technologies typically used for assessing chemicals transported in groundwater to the river can be divided into two categories: passive and active. A brief description of proposed sampling techniques for each category is provided below. Specific sampling techniques for physical and chemical groundwater data will be described in FSPs for individual sampling events.

Passive Sampling Devices. Passive devices include semipermeable membrane devices (SPMDs), diffusion samplers, and peepers. Passive sampling techniques involve placing a sampling device in sediment or in the water column and allowing that device to reach chemical equilibrium with the surrounding media over time. The time required for equilibrium is dependent on the properties of the contaminants of interest. Passive devices provide quantitative or semi-quantitative results that may be used in a variety of RI/FS applications.

Active Sampling Devices. Active sampling devices are designed to obtain a representative concentration of a chemical in groundwater, including in the Transition Zone. Samples obtained using active sampling devices are concentrations representing a spatial and temporal point. Active sampling devices include mini-piezometers, temporary direct-push devices (e.g., Geoprobes®), and multi-level sampler devices.

7.3 ECOLOGICAL RISKS

Ecological receptors may be exposed to chemicals resulting from historical and ongoing releases and/or sources within Portland Harbor. Potential receptors in the ISA include species of aquatic plants, amphibians, reptiles, benthic and epibenthic invertebrates, fish, birds, and mammals. Exposure may occur through direct contact with sediment or water or through ingestion of sediment, surface water, and prey items. Tables 7-6 through 7-10 present the DQO process for assessing ecological risk. Appendix B describes the ERA approach.

7.3.1 Problem Description

Chemicals in sediment, water, or biota in the ISA may result in unacceptable risks to ecological receptors. The objective of the baseline ERA is to estimate potential risks to ecological receptors associated with exposure to chemicals resulting from historical and ongoing releases or sources within the ISA.

7.3.2 Data Uses

Data collected to support the ERA will be used to determine whether chemicals in sediment, water, or biota resulting from historic and ongoing releases or sources in the ISA cause unacceptable risks to ecological receptors and warrant consideration of further investigation or possible response action.

7.3.3 Data Needs

Chemicals in sediments (including solid and aqueous phases) and surface water may have adverse effects on ecological receptors through direct contact or ingestion of sediment and surface water. Therefore, areas where potential receptors could be exposed to sediments and surface water need to be identified. These exposure areas will be identified by evaluating the ecology, particularly the foraging habits, of all receptor species. Sediment and surface water data will be collected from those areas where exposure could occur.

Biota that have accumulated chemicals from surface water and sediment in the ISA could pose risks to ecological receptors that ingest those biota. Therefore, to evaluate potential risks to ecological receptors that prey on biota within the ISA, tissue data from representative prey items are needed.

Groundwater may be a source contributing to elevated chemical concentrations within the ISA. Therefore, to evaluate whether the discharge of contaminated groundwater to the ISA presents a risk, exposure points for groundwater will need to be identified. A review of historic data, physiochemical aspects of chemicals in groundwater, and the potential for ecological risks not already captured in the aquatic invertebrate risk evaluation needs to be completed.

7.3.4 RI/FS Tasks

As discussed in previous sections, the RI/FS will be an iterative process that includes multiple rounds of data collection. Data to support the ERA includes the following:

- Pre-AOC data
- Historic Category 1 data
- Round 1 data
- Round 2 data
- Round 3 data (if necessary to reduce uncertainties).

The following specific RI/FS tasks will address the data needs of the ERA:

1. All of the pre-AOC data collected under the stipulated agreement were used to develop the preliminary conceptual site model for the ERA.
2. The historic Category 1 data will be used in estimating risk to ecological receptors. Historic Category 1 and 2 data were used in scoping the ecological risk assessment (e.g., to better understand tissue concentrations from historic studies and to better understand the trends in sediment chemical distributions).
3. During Round 1, surface sediment samples were collected in areas that were identified, using existing data, as potential sources and provide ecological habitat for selected receptors. These data will be used in estimating risks.
4. Collocated with the sediment samples in Round 1, crayfish and sculpin tissue, benthic community, and, where possible, clam tissue samples were collected. The exact analyte list for each sample type is described in the Round 1 QAPP. These analytical results and benthic community characteristics will be used to refine the conceptual site model and as input into the preliminary risk evaluation. These data will also be used to assess the relationship between sediment and tissue concentrations.
5. In addition to these data, physical system and source information (e.g., bathymetry, seep reconnaissance) will be applied in the evaluation of the effect of groundwater on exposure pathways and its potential risk to infaunal invertebrates.
6. Data pertaining to the physical system (e.g., bathymetry) will be used to update the exposure scenarios for the ERA.

The following additional tasks will be performed to fill data needs for the baseline ERA:

1. Collection of surface water chemistry data in quiescent areas within the ISA for the purposes of determining exposure concentrations to aquatic invertebrates, fish, and amphibians from the surface water pathways.
2. Collection of bulk surface sediment samples for bioassay testing across the gradient of chemical concentrations observed in historic and 2002 data.
3. Collection of additional sediment chemistry samples, as needed, to fill any data gaps that remain after the 2002 sampling (e.g., assessment of the dietary pathways to fish and wildlife).
4. Collection of site-specific data, as needed, to parameterize the food web model that will be used to establish sediment preliminary remediation goals.

Data collected in Round 2 will be used to further refine the CSM and identify remaining data gaps. Additional data may be collected in Round 3 as needed to complete the risk assessment. The information collected in Rounds 1, 2, and 3 will be applied in the draft baseline ERA.

7.4 HUMAN HEALTH RISKS

Human receptors may be exposed to chemicals that are a result of historical and ongoing releases and/or sources within the ISA. Potential human uses in the ISA include occupational, recreational, transient, and fish consumption scenarios. Exposure may occur through direct contact with sediment or water or through ingestion of fish or shellfish. Appendix C contains the HHRA approach.

7.4.1 Problem Description

Chemicals in sediment, water, or biota in the ISA may result in unacceptable risks to some human receptors. However, these risks have not been estimated for human receptors. The objective of the HHRA is to estimate potential risks to human health associated with exposure to chemicals that are a result of historical and ongoing releases and/or sources within the ISA. Details of the DQO process used to develop data needs for the HHRA are included in Table 7-11.

7.4.2 Data Uses

Data collected to support the HHRA will be used to determine whether chemicals in sediment, water, or biota that are the result of historic and ongoing releases and/or other sources to the ISA cause unacceptable risks to human health and warrant consideration of further investigation or possible response action.

7.4.3 Data Needs

Chemicals in sediments and surface water may have adverse effects on human receptors in areas where direct contact with those media occurs. These areas need to be identified, and human activities that could occur in those areas need to be evaluated to assess the potential for direct contact with sediment or surface water. Sediment and surface water data are then needed to evaluate risks from human activities that could result in direct contact.

Although groundwater is not anticipated to result in significant risks to human health, groundwater could result in potential risks to human receptors if direct contact with groundwater seeps occurs on a frequent basis and chemical concentrations in groundwater are high enough to pose a risk. Direct contact with groundwater may be a complete exposure pathway for human receptors at some beaches designated as human use areas, specifically at locations where groundwater seeps are found on the beach above the water line. Therefore, potential exposure points for seeps need to be identified. Results of a field reconnaissance survey conducted during low water to identify potential groundwater seep locations above the water line will be reviewed to determine if any of these seeps are located within potential human use beaches. Available upland groundwater data near any beaches identified in this review would also need to be reviewed to assess the potential for the presence of chemicals in these groundwater seeps at concentrations of concern. Additional data needs for the HHRA related to the groundwater pathway will be assessed as part of the groundwater evaluation, as described in Section 7.2.3.

Biota that have accumulated chemical constituents from surface water and sediment in the ISA could pose risks to human receptors who ingest those biota. Therefore, to evaluate risks to human health associated with consumption of biota, the fish and shellfish species that are caught in the ISA and consumed by humans need to be identified. If the HHRA indicates that consumption of biota from the ISA could result in unacceptable risks to human health, a model will be needed to estimate sediment and water chemical concentrations that could result in the chemical concentrations detected in biota tissue. Site-specific (and congener-specific, if needed) biota sediment accumulation factors (BSAFs) and bioconcentration factors (BCFs) will likely be required as inputs to the model. Data needed for the model will be collected during Rounds 2 and 3, as needed.

7.4.4 RI/FS Tasks

As discussed in previous sections, the RI will be an iterative process that includes multiple rounds of data collection. Data to support the HHRA include the following:

- Pre-AOC data
- Historic Category 1 data
- Round 1 data
- Round 2 data
- Round 3 data (if necessary for the food web model).

The draft baseline HHRA will be completed following Round 3.

RI/FS tasks that have been conducted to date to support the HHRA include the following:

1. The preliminary conceptual site model for the HHRA was developed based on pre-AOC data.
2. Historic data were compiled and categorized. Historic Category 1 data will be evaluated to identify data that could be used in the baseline HHRA. The results of this evaluation will be submitted to EPA as an interim deliverable. Historic Category 1 data will only be used in estimating risk to human receptors if appropriate for the receptors and exposure pathways that will be evaluated in the HHRA. Historic Category 1 and 2 data were used in scoping the HHRA (e.g., to better understand tissue concentrations, to begin evaluation of trends in sediment chemical distributions).
3. During Round 1, beach sediment samples were collected in human use areas where direct contact with sediment could occur. The basis for selecting human use areas is described in Appendix C. Because potential contact with beach sediment would be ongoing and would occur throughout a beach area, composite surface sediment samples were collected to be representative of the type of exposure that could occur. Beach sediment samples were collected during low tide and at low water when the maximum beach area was exposed. These data will be used in estimating risks to human health.
4. A limited qualitative survey was conducted to identify target fish and shellfish species for human consumption. The survey included interviews with two local fishers, as well as a review of the investigation by the Oregonian and the limited surveys of other portions of the Willamette River (ATSDR 2002). Based on the results of the survey and to support the HHRA, four resident fish species and shellfish (crayfish) tissue samples were collected in the ISA during Round 1. Fish and shellfish tissue data collected in the ISA during the Round 1 field studies will be used

in the baseline HHRA to estimate potential risks to human health from fish consumption.

5. A reconnaissance survey of groundwater seeps, conducted in October 2002, found seeps at or near 12 beaches identified as potential human use areas. A methodology for evaluating seeps for potential human health risks will be discussed with EPA and its partners and incorporated into the HHRA Approach (Appendix C), when approved.

The following additional tasks will be performed to fill data needs for the baseline HHRA:

1. Composite surface sediment samples were collected at human use beaches to be representative of potential human exposures, but these samples may not be appropriate for evaluation of response actions. Therefore, the results of beach sediment samples from Round 1 will be compared to appropriate Region 9 PRGs for soil to evaluate whether discrete beach sediment samples are needed. If the composite sample for a beach exceeds risk-based screening levels, that beach will be identified and the need for further data collection will be evaluated. Results of the evaluation of the beach sediment samples will be submitted to EPA as an interim deliverable. If needed, additional beach sediment samples will be collected during Round 2.

2. Upland groundwater data will be compiled for the RI/FS. The upland groundwater data for sites adjacent to beaches where groundwater seeps were identified will be reviewed during Round 2. The data review will evaluate whether chemicals might be present in groundwater at the point of discharge in human use areas.

3. Surface water samples will be collected in Round 2 within quiescent river areas near selected recreational beaches and unsecured riverfront areas where transient encampments have been observed. These are areas where swimming and other direct contact could occur. These data will be used to evaluate potential risks to human health associated with ingestion of, or dermal contact with, surface water. To address site characterization data needs, surface water samples will also be collected during Round 2 from three river transect locations. These samples should be representative of surface water conditions in non-quiescent areas within the ISA. Samples collected from these locations could also be used to evaluate potential direct human contact with surface water (e.g., during windsurfing) in non-quiescent areas of the ISA.

4. Finally, if the risk assessment finds that fish consumption may result in unacceptable risks to human health, a food web model will be needed to evaluate the relationship between sediment, surface water, and tissue. Site-specific data (sediment, surface water, and prey items) will be collected, as needed, to support the food web model that will be used to establish sediment preliminary remediation goals based on detected concentrations of chemicals in fish tissue.

The data collected from the RI/FS tasks above will be used to complete the baseline HHRA.

Sturgeon, adult spring Chinook, and adult Pacific lamprey were collected in the summer of 2003 through a cooperative effort of the ODHS, ATSDR, Oregon Department of Fish and Wildlife (ODFW), the City of Portland and EPA, Region 10. Although these data were not collected as part of the RI, they will be evaluated by the LWG and used in the HHRA. EPA and LWG will use a collaborative process for identifying data needs, data gaps, data uses and evaluations for salmonids, lamprey and sturgeon.

8.0 FEASIBILITY STUDY APPROACH

Though the primary goal of the RI and baseline risk assessment is to determine the areas that may require cleanup, the goal of the FS is to identify the appropriate remedy consistent with the nine CERCLA criteria. The RI and risk assessment are primarily information-gathering and evaluation tasks to understand existing conditions at the Site, while the FS is concerned primarily with identifying reasonable future actions that could be used to conduct a remedial action consistent with CERCLA requirements. Consequently, the FS relies greatly on the data collection and existing conditions description provided by the RI and risk assessment. However, some information gathering must also occur specifically for the FS so that various proposed actions can be evaluated for their potential to succeed (i.e., feasibility) in cleaning up the Site.

Because certain FS tasks are primarily concerned with collecting FS-specific information, they are described using an organization similar to that found in Section 7 for risk and chemical distribution/source information (a DQO style presentation). However, the portions of the FS that are concerned primarily with evaluating the outputs of the RI and risk assessment, as well as developing proposed actions, are described more generally as a series of data analysis and deliverable steps.

In the following sections, the overall FS process and major tasks are briefly described (Appendix A contains the detailed FS process). Key tasks are then described in more detail and, where appropriate, are presented in the DQO style of the previous section. Wherever possible, the information flow that will occur between RI, risk assessment, and major FS tasks is illustrated. However, because the FS essentially relies on all of the information generated by the previous studies, there may be specific pieces of information that will be used but are not specifically identified for a particular FS task. For example, bathymetry is essential to almost every FS task, but use of this information is not repeatedly identified throughout the text.

8.1 FS PROCESS AND MAJOR STEPS

The FS process can be understood in two basic ways that are illustrated in Figure 8-1:

- The sequence of evaluation tasks that will lead to a selected remedial alternative
- The information that will flow from the RI/risk assessment/FS data collection to major FS tasks.

The major tasks for performing the FS are described below.

Preliminary Planning Tasks. As a part of this Work Plan, several memoranda have been prepared to describe specific processes that are proposed to evaluate existing information or to help in planning of the FS (Appendix A, Attachments A1-A4):

- Development of preliminary RAOs
- Description of a proposed disposal facility siting process
- Identification of potential sources of capping materials
- Analysis of natural attenuation data gaps.

These memoranda generally lay out processes or information that will be of later use in the FS. How these proposed processes fit into the overall project are further described below and detailed in the Appendix A attachments.

RAOs. The FS must start with a description of the objectives of the remediation. These form the basis from which the success and effectiveness of proposed actions can be evaluated. This task determines the goals of the entire FS process. The RAO memorandum describes the Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered (TBC) initiatives that will be used in determining an appropriate RAOs and a Site remedy. Compliance with ARARs is one of the CERCLA “threshold” criteria (the other being overall protection of human health and the environment) for evaluation of alternatives.

Treatability Studies. Treatment is one potential remedial alternative. In some cases, laboratory- or pilot-scale studies must be conducted to understand the feasibility of treatment technologies. This task involves determining the need for such studies and conducting these studies when and if they are needed.

Facility Siting Studies. Many remedial options include the removal of sediments and disposal or treatment at some other location. This task will identify potential disposal site and treatment locations that may need to be evaluated for the FS.

Natural Attenuation Studies. Natural attenuation is one type of remedial alternative that will require data collection on the physical and chemical systems of the river to understand its potential feasibility. This task includes both the data collection and data evaluations that will be conducted to determine the feasibility of this particular option.

Development, Screening, and Evaluation of Remedial Alternatives. This task involves the first step in identifying potential remedial alternatives for the Site. It will proceed in a series of remedial alternative development and evaluation steps that will rely on various types of data analysis including:

- Determination of SMAs and, for SMAs in which dredging is considered a potential remedial action, volumes of sediment requiring remediation

- Evaluation of remediation and disposal site engineering properties
- Analysis of the recontamination potential at remediated sites.

This step in the FS process follows EPA (1988) guidance on conducting FSs and includes evaluation of alternatives against the three screening criteria of effectiveness, cost, and feasibility as well as detailed evaluation of alternatives against the nine CERCLA evaluation criteria.

A preliminary list of remedial technologies that will be considered in the development of remedial alternatives has been developed and is presented in Appendix A, Attachment A1. In summary, the remedial technologies for sediments that will be considered in the development of remedial alternatives are:

- No Action
- Institutional Controls
- Natural Attenuation
- *In-situ* Containment (e.g., capping)
- *In-situ* Treatment
- Removal and Disposal (e.g., aquatic, nearshore, or upland confined disposal)
- Removal and Treatment

In addition, other remedial technologies that may apply to chemicals in fish tissue and/or water are discussed in Appendix A, Attachment A1.

FS Report. This report describes all of the above data collections, data evaluations, and remedial alternative development and evaluation steps. The purpose of this task is to present the recommended remedial alternatives to EPA and its partners for review and eventual agreement, and, finally, to assist in development of the ROD.

The following sections describe the methods and approach to each of these tasks in more detail.

8.2 REMEDIAL ACTION OBJECTIVES

Preliminary RAOs were developed for the project and are described in the Preliminary Draft Remedial Action Objectives Technical Memorandum (see Appendix A, Attachment A1). This section summarizes the preliminary RAOs defined in that technical memorandum. It should be noted that the technical memorandum also describes the process of how these preliminary RAOs were determined. In general, the process closely followed CERCLA guidance (EPA 1988). RAOs provide a context for the FS and, when established early in preliminary form, help focus the FS toward effective remedial alternatives.

It is important to note the following specific definitions of terms used in the preliminary RAOs.

Reduce Risks. Lessening the unacceptable risks from chemicals by lowering their concentrations, mobility, bioavailability, toxicity, or exposure to receptors. The assessment endpoints used to define unacceptable risks are presented in detail in the ERA and HHRA approaches (Appendices C and D). In summary, the ERA endpoints are the survival, growth, and reproduction of relevant ecological receptors. For human health, the endpoints are carcinogenic and non-carcinogenic effects to people (using EPA's typical risk range for cancer risks of 1×10^{-4} to 1×10^{-6}). Use of the word "reduce" is not intended to imply that the risk reduction must occur through a decrease in chemical concentration in the matrix of interest.

Acceptable Levels. Risks posed by chemicals that are below unacceptable adverse risk or harm to either the ecological or human health receptors identified above using the assessment endpoints defined in the ERA and HHRA approaches (Appendices C and D, respectively). These risk levels will be eventually quantified through the baseline risk assessment.

The five preliminary RAOs listed in Section 6.1 all follow the specific requirements of RAOs in EPA (1988) guidance. The FS will consider "background" following EPA guidance (EPA 2002b) on the use of background in RI/FS evaluations and other relevant EPA Superfund guidance. The intent is that RAOs will not result in remedial action (or cleanup) levels that are below background levels, including anthropogenically caused background levels. This is consistent with EPA (2002b) guidance on consideration of background in risk management. Site-specific background levels will be identified in a future technical memorandum (see Secton 6.3.2).

In addition to the RAOs the following general objectives (which are not RAOs) for the remedial action are considered important by the LWG.

- Promote remedial actions that do not limit current or planned waterway, municipal, commercial, industrial, recreational, or Tribal ceremonial uses.
- Promote remedial actions that are feasible for the physical system of the Willamette River.
- Integrate remedial actions with NRDA findings and restoration plans, where appropriate.

As detailed in the technical memorandum, RAOs will be developed and refined at the start of the formal FS (after Round 3 sampling) in coordination with EPA. An integral part of developing RAOs is considering ARARs. Appendix A, Attachment A1, reviews ARARs and TBCs that may be appropriate for use in this FS.

8.3 TREATABILITY STUDIES FOR SEDIMENTS

Treatability study tasks are described in detail in Appendix A. A summary is provided below.

8.3.1 Problem Description

Treatability studies provide information on the suitability of site-specific sediments or other matrices for treatment technologies and help to understand how various treatment technologies may or may not be viable for this specific site. Consistent with the SOW, if existing information is sufficient to determine suitable technologies and/or judge their appropriateness without treatability studies, treatability studies do not need to be conducted.

8.3.2 Decisions and Data Uses

Sufficient information must be available to compare, in a consistent manner, treatment technologies with all other technologies. If literature information is insufficient, treatability studies for specific technologies may be necessary. Two basic preliminary decisions must be made:

- Which treatment technologies are effective and cost-competitive (potentially suitable) as compared with other general response actions?
- For those potentially suitable technologies, would treatability studies be needed to determine the appropriateness of the technologies for this specific site?

8.3.3 Data Needs

To make the preliminary decisions, a literature survey of existing treatment technologies is needed. If this information is insufficient to compare, in a consistent manner, treatment technologies with other remedial alternatives, then treatability tests should be conducted.

8.3.4 Treatability Study Tasks

Per Section 8.1.1 of the SOW, the LWG will conduct a literature survey on existing sediment treatment methods. Information on performance, relative costs, applicability, removal efficiencies, operation and maintenance requirements, and implementability of candidate technologies will be compiled and evaluated.

Based on this review and data evaluation, the LWG will recommend to EPA in a technical memorandum (Treatability Study Literature Survey Technical Memorandum) whether treatment is a feasible and cost-effective general response action for sediments. If so, the specific types of treatment technologies likely to be feasible and cost-effective (and why) will be presented and discussed in a technical memorandum. Finally, the memorandum will indicate whether site-specific treatability studies are needed to further evaluate any of these technologies.

If a decision is made to perform treatability studies, the LWG will select in conjunction with EPA the type of treatability testing to use (e.g., bench vs. pilot). A brief technical memorandum (called a statement of work in the AOC and defined as the Evaluation of Treatability Studies Technical Memorandum) will be prepared by the LWG that lists the candidate technologies, identifies the scale at which they will be tested (pilot vs. bench), and lists available facilities/sites at which the testing can occur. Testing will occur on the basis of this memorandum.

As shown in Figure 8-1, the Literature Survey Technical Memorandum will be provided in time to refine general response actions (immediately after Round 3 sampling). If treatability tests are conducted, they will be completed in time for the refinement of alternatives step in the FS process.

8.4 FACILITY SITING STUDIES

This FS task is described in detail in Appendix A, Attachment A2, and is summarized here.

8.4.1 Problem Description

Sufficient information must be available on potential sites for sediment disposal to reasonably evaluate dredging or other removal remedial options. The actual availability, distance, and configuration of facility sites affect many aspects of the remedial alternative, including the major FS selection criteria of effectiveness, cost, and feasibility.

8.4.2 Decisions and Data Uses

Sufficient information must be available on disposal sites such that the removal option can be reasonably evaluated in the FS consistent with other alternatives. All types of disposal sites are to be considered, such as aquatic, nearshore, upland, and currently operating landfills.

8.4.3 Data Needs

The locations, limitations, and general configurations of potential sites must be known. Where these are currently operating landfills, this would include tipping and other commercial fees as well as taxes.

8.4.4 Facility Siting Tasks

The following major steps to facility siting and disposal site identification are presented in Appendix A, Attachment A2:

1. Define the geographic limits of the study area to be considered for facility siting.
2. Estimate the volume of sediments that might be disposed based on Round 2 information available.
3. Evaluate the study area for sites of appropriate size (given Step 2 volume assumptions) and use preliminary screening criteria to create a preliminary inventory of sites.
4. Determine the specific volume and the chemical, physical, and geotechnical characteristics of the sediments to be disposed (information available after Round 3 sampling).
5. (Optional) Rescreen sites from Step 3 to create a refined site list, based on the information from Step 4 and any additional useful criteria that become evident from the information gathered in Step 4. (If Step 4 information is insufficient to further refine the site list, then this step will be skipped.)
6. Conduct a brief evaluation of each site on the refined list (or preliminary list of Step 5 is skipped) using CERCLA-based criteria to arrive at a final ranked list of potential sites.

This process will create a "menu" of options that can be used in remedial alternative development described below. In addition, Round 3 sampling may also include collection of engineering samples from prime candidate disposal locations prior to Step 4. This would allow further refinement of remedial alternatives involving disposal sites.

The facility siting process invokes some of the substantive requirements of certain ARARs, such as for consideration of in-water disposal, Section 404(b)(1) criteria should be considered during the selection and screening of the alternatives evaluation. For example, an in-water disposal option may not pass the 404(b)(1) alternatives analysis if the only upland disposal site is a commercial landfill. Information and consideration of one or more on-site upland disposal sites in addition to a landfill may be required to fulfill 404 requirements. It is anticipated that early outreach on the proposed disposal site list for FS evaluation may be conducted to help understand the range of potential public opinion on the sites.

8.5 NATURAL ATTENUATION STUDIES

Appendix A, Attachment A4, describes natural attenuation studies in detail. This section summarizes those studies. The DQO process for natural attenuation is summarized in Table 8-1.

8.5.1 Problem Description

For natural attenuation to be evaluated as a potential remedial alternative for portions of the Site, it must be predicted whether the processes present at the Site are likely to cause natural attenuation to occur, and if so, how quickly that attenuation will progress. Because natural attenuation occurs through numerous physical, chemical, and biological processes, the most common method of predicting the potential for natural attenuation is through the use of computer models that require specific data inputs. Consequently, considerable information on natural systems at the Site must be collected and evaluated in time for the evaluation of this alternative in the FS.

8.5.2 Decisions and Data Uses

It must be determined whether there is a reasonable probability that natural attenuation is a feasible alternative for any portions of the Site. Data must be collected on the physical/chemical system to allow adequate modeling of the Site.

8.5.3 Data Needs

Data needs are determined by the specific computer models proposed to predict the potential for natural attenuation. The selection of models is described in Appendix A, Attachment A4. Table 8-2 summarizes those data needs based on the models selected in Appendix A. The steps referred to in Table 8-2 are outlined below.

8.5.4 Data Collection and Evaluation Tasks

A tiered approach to natural attenuation studies will be followed to focus resources on the areas of the site where natural attenuation may be a plausible alternative. The following three-step process is proposed:

- **Step 1.** Identify areas that have basic processes that are potentially suitable for natural attenuation based on information already available for the river system.
- **Step 2.** Conduct select sampling (in Round 2) within a few areas that appear characteristic of the range of potential natural attenuation processes at the Site and simple probabilistic modeling. Eliminate from future evaluations the types of areas that have a low probability of having processes that support natural attenuation.
- **Step 3.** Conduct detailed sampling (in Round 3) and modeling in SMAs that appear to have suitable processes for natural attenuation (based on Step 2 results) to determine viability and rate of natural attenuation.

Step 1 identifies areas of the river that potentially have natural attenuation processes that are characteristic of types or river conditions (e.g., embayments, backwaters, eddies, slips, otherwise protected areas). These areas will be reviewed, and particular sites will be selected for sampling in Step 2 that are representative of the range of overall site characteristics that may be conducive to natural attenuation. These characteristic areas do not represent proposals for natural attenuation, but will help focus future natural attenuation sampling in Round 3. Based on Round 3 information, modeling will be conducted that will identify specific areas where natural attenuation may be a viable remedial alternative. The data collection proposed to support these steps is summarized in Table 8-3. Information for some parameters will be obtained from either literature values and/or other studies conducted for this RI/FS, including STA® results and hydrodynamic modeling results. Information on groundwater conditions will be obtained through LWG lead groundwater studies proposed elsewhere in this Work Plan, as well as groundwater data collected by individual parties as a part of DEQ-directed upland cleanup efforts.

The information from Round 3 natural attenuation sampling and subsequent modeling will be used to define areas that may be suitable for natural attenuation as a remedial alternative.

8.6 SEDIMENT MANAGEMENT AREAS AND VOLUMES

The first step in the FS is defining areas and volumes of sediments where remediation will be necessary. This includes both area-specific risks and sediments that cause risks through site-wide processes such as bioaccumulation of chemicals.

8.6.1 Problem Description

At the conclusion of the RI and baseline risk assessment process, the nature and extent of sediment contamination and risks (including site-wide risks) will be understood in sufficient detail to define SMAs and volumes of sediments potentially posing risks. SMAs are a tool for defining sediment regions within the Site that can be discretely considered for development of remedial alternatives. The development of SMAs does not preclude the evaluation and inclusion of site-wide risks in the definition of sediments requiring cleanup or development of remedial technologies for those site-wide risks. The FS will develop comprehensive alternatives that evaluate natural attenuation, capping, dredging and other options for these areas. Therefore, the sampling completed at the end of Round 2 should provide sufficient types and amounts of information to preliminarily define these areas. Additional data will likely be collected in Round 3 to further refine some SMAs and sediment volumes, and generate data needed to evaluate remedial alternatives in the FS. In other cases, refinement of SMAs can be conducted after the ROD in the RD/RA phase of the project.

8.6.2 Decisions and Data Uses

The primary objective of the FS is to identify a menu of remedial options for SMAs within the Site. These remedial options could apply to SMAs singly, in combination, or to the entire site. Because for many types of risks, the level of risk will vary between regions of the Site, the Site will be broken down into a “mosaic” of discrete areas (i.e., SMAs) where remedial options can be evaluated and applied, leading to the development of remedial alternatives. The definition of this mosaic of SMAs is the primary decision required.

The decision requires input from a wide variety of data types (discussed in the next section). These data will be used define the mosaic of SMAs that will be used in the FS.

8.6.3 Data Needs

To delineate SMAs, the following types of evaluations based on site data are needed:

- A delineation of areas posing unacceptable risks for ecological and human health receptors both within regions of the site and site-wide
- A categorization of risks within areas that pose unacceptable risks (e.g., areas that pose a principal threat and/or “high” risk versus relatively “low” risk areas)
- A categorization of site-wide risks and the areas that contribute to those site-wide risks

- Delineation of sediment volumes (vertical and horizontal extent) that pose unacceptable risks, where deeper sediments may pose potential future risks
- Delineation of sediment volumes sufficient for evaluation of remedial alternatives in the FS (particularly for areas where dredging is likely due to navigation, water dependent, or other similar uses)
- Identification of physical environments (e.g., erosive areas, deposition areas, nearshore benches, navigation channels, depressions)
- Identification of habitat types and areas of special habitat significance
- Identification of river and shoreline land uses that affect remedial alternatives (e.g., navigation channels, current and future marine facilities, proposed shoreline developments)
- Identification of areas that may be impacted by ongoing sources (upstream and/or upland).

The information that will support these evaluations includes the following:

- **Ecological Risk Areas**: based on the results of the ERA, which will also provide information on relative risk to determine principal threat areas as well as areas of relatively “high” vs. “low” risk. Site-wide ecological risks will also be included.
- **Human Health Risk Areas:** based on the results of the HHRA, which will also provide information on relative risk to determine principal threat areas as well as areas of relatively “high” vs. “low” risk. Site-wide human health risks will also be included
- **Volumes**: surface and subsurface sediment chemistry
- **Physical Environment**: SPI, STA®, grain size, low- and high-flow bathymetry, radioisotope cores, sediment trap data, preliminary natural attenuation modeling results, hydrodynamic/sediment transport modeling results, and site geography
- **Habitat Types:** based on the results of the ERA
- **River Uses**: navigation channel limits, aerial photographs, property maps, and information from property owners, land use and marine master planning documents.

- **Ongoing Sources**: in-river surface sediment, Transition Zone water (if collected), and surface water chemistry, data collected by DEQ through upland cleanup actions, sediment trap data, and subsurface sediment chemistry.

8.6.4 SMA and Volume Tasks

The FS tasks needed to define SMAs and volumes are described below.

Review Round 2 Data Collection for Preliminary SMAs

The preliminary risk assessment results (based on data for tissue chemistry, surface sediment chemistry, subsurface sediment chemistry, beach sediment chemistry, bioassays, and water chemistry), bathymetry, SPI, STA®, and grain size, as well as hydrodynamic modeling, have been or will be collected in Rounds 1 and 2. These tasks are described in detail in Section 7. How those tasks will be adapted to fulfill the SMA data needs is described below.

The biased surface and subsurface sediment sampling approaches proposed for site characterization and risk tasks for Round 2 include samples that target locations where specific information is desired, such as filling potential spatial data gaps, determining areas where risk pathways or receptors exist, and understanding source effects from potential upland sources. Altogether, these samples cover a wide range of general site conditions within the ISA, including nearshore areas, deeper areas, the navigation channels, maintenance dredge areas, depressions, benches, potential deposition and scour areas, and in and around slips and features like Swan Island. Because of this wide coverage, this information can be used to define preliminary SMAs at the end of Round 2 sampling that account for unacceptable risks including site-wide risks and physical components of the Site.

As described in the natural attenuation task above, preliminary information will also be available for radioisotope cores at the end of Round 2. This information will help to define potential deposition areas of the Site. However, it will not be essential to the development of preliminary SMAs after Round 2. As described above, preliminary hydrodynamic/sediment transport and natural attenuation modeling tasks will be completed by the end of Round 2 data collection. This information will be useful in describing the range of physical environments present at the Site, and will be input directly into a preliminary definition of SMAs that account for sediment depositional, dynamic equilibrium, and erosive areas.

Information has been gathered on the general existing conditions of the Site, including site geography, navigation channel limits, aerial photographs, and property maps that can be input directly into SMA definition. Information has also been gathered on the status of DEQ investigations of potential sources within the ISA. Finally, the nature and extent of contaminants in water and sediment (including upland groundwater and Transition Zone information) will provide additional information that will also be factored into SMA definition relative to potential ongoing sources and potential background levels of chemicals.

The primary additional tasks that are not part of other efforts and have been identified to help define SMAs are:

- Obtain periodic updates of DEQ-gathered information on sources through the course of Round 2 so that these can be input into the preliminary SMAs
- Obtain information from land owners about potential future uses of shorelines and waterways.

This second task will be conducted by interviewing major landowners along the shoreline, reviewing both dredging records and existing maintenance dredging permits, reviewing the City of Portland Comprehensive Plan and Port of Portland marine master plan, to determine areas that are or will be routinely maintained for navigation. It must be realized that in many cases landowners may either be uncertain about potential future uses and/or unwilling to provide this information for commercial reasons. Consequently, where information gaps exist, it will be assumed for SMA definition that existing uses would be maintained at shoreline sites.

Define Preliminary SMAs and Volumes

There is no well-defined guidance or process for defining SMAs that applies to all situations. SMA development will be an iterative process that considers how areas of risks (including site-wide risks), volumes of sediments, physical environments, biological environments, and site uses overlap. It will primarily be a mapping exercise. Sediment areas that define unacceptable ecological risks, unacceptable human health risks, physical environments (e.g., erosive, depositional, benches, depressions, and landforms), and site uses will be separately mapped. This includes mapping areas of discreet risk as well as sediment or sources that contribute to site-wide ecological or human health risks. Where possible, the individual locations (such as surface sediment stations) that are used to define the areas will also be shown on the maps. These separate layers and sampling locations will be overlaid to see how they interact and group. Generally, SMAs will be defined to minimize the number of risk, physical, and site use boundaries that are crossed by each SMA while keeping the SMAs at sizes that are reasonable to evaluate from an engineering perspective. Areas of relatively high risk (i.e., principal threat areas or “hot spots”) will also be considered in developing SMAs. Principal threat areas may either be parts of SMAs or uniquely separate SMAs. The general magnitude of risks as described in the ERA and HHRA documents will also be considered using information such as hazard quotients, risk probabilities, and other risk estimates. The identification of principal threat areas will assist in the evaluation of remedial alternatives that may better address areas of particularly concentrated or toxic chemicals that differ in character from other SMAs or the Site in general.

It should be noted that risks may be defined either on an area basis either regionally or over the entire site or an extrapolation of areas from one or more point samples. Where risks are based on point samples that are extrapolated to areas, spatial or statistical procedures may be used to define the areas of risks. Where risks are available on an area-weighted average basis (e.g., over a home range or a swimming beach or the entire site, where appropritate for the risk pathway involved), these areas will be used to define the risk area component of the overlay. In some cases, such as risks involving bioaccumulation pathways, the area posing risk may be a large portion or even the entire site. This situation will also be mapped for the appropriate chemicals and pathways.

Once a preliminary SMA map is defined, it will be examined to determine where SMA boundaries are based on relatively limited data sets. If it appears that further definition of these boundaries is needed in order to develop a reasonable set of remedial alternatives for evaluation in the FS, then these areas may be targeted for additional sampling in Round 3. If this information is not critical to the FS, refinement of SMA boundaries may be left to the RD/RA phase after the ROD.

Refine SMAs After Round 3 Data Collection

It is anticipated that after Round 3 data collection, the SMAs will be refined. The following information will likely be available at that time:

- Additional natural attenuation sampling (water samples, sediment traps, radioisotope cores) and modeling results
- Additional subsurface sediment cores intended to define volumes of sediment posing risks.

These data will be used to refine SMAs relative to physical system types (e.g., erosion or deposition areas), as well as areas that may be specifically suited for one or more remedial types (e.g., natural attenuation).

Subsurface coring in Round 3 will be conducted to specifically determine the depth of contamination in SMAs that appear to be potential candidates for dredging (either through remedial design or for navigational purposes) or in areas that have a potential to erode over time or during major flood events. This information may also be gathered for principal threat areas. Chemical levels in subsurface sediments would be compared to risk-based levels established in the baseline risk assessments to determine volumes of impacted sediments.

8.7 RECONTAMINATION POTENTIAL

8.7.1 Problem Description

To the extent practicable, ongoing sources should be controlled before remedial actions are implemented so that recently cleaned areas are not re-impacted by the same or other ongoing sources. This will be accomplished by performing the following tasks:

1. Developing and understanding of source processes through existing information (as reviewed in Section 3)
2. Developing a conceptual site model of ongoing sources that could affect the river (as reviewed in Section 5.1.1)
3. Collecting data to understand ongoing sources (as reviewed in Section 7.2)
4. Obtaining and reviewing data from DEQ on upland sources that are gathered as a part of various upland site investigations
5. Referring to DEQ-identified ongoing sources that appear to be impacting the river for new or further source control implementation at those sites
6. Identifying in-river sediment sources that may be adversely affecting downstream areas for cleanup under the FS alternatives.

This approach will include evaluating all types of potential sources discussed in Section 3, such as outfall discharges, groundwater discharges, spills, bank erosion, chemical leaching from surfaces, atmospheric deposition, and water and sediment transport within the river.

The above tasks will be undertaken by the LWG and/or referred to DEQ for additional action (as noted above) and will be the primary methods for identifying and controlling sources early in the cleanup process. It is important to note that the recontamination evaluation discussed in this section is not the main method of source control, which is regulated by DEQ for upland sites. Rather, the recontamination evaluation serves as a later verification that sources are suitably controlled for remediation to proceed. If this evaluation indicates sources may not be suitably controlled, then this information will be referred to DEQ for additional investigation of upland sources before actual construction of in-water remediation could commence.

Once sources are controlled to the extent practicable, a method is needed to assess whether recontamination may occur after construction of in-water cleanup actions. This recontamination evaluation will be undertaken after identifiable sources have been controlled or are being controlled, but before completion of the FS.

The evaluation of potential recontamination after primary source controls depends on whether concentrations from various sources stay at post-source control levels established through the above efforts and the effect of these concentrations on future cleanup actions, and if the cleaned up areas stay clean. If either of these conditions are not expected to be met, further source controls should be implemented prior to construction of the cleanup actions. Implementation of additional source controls is expected to be carried out by upland property owners with direction by DEQ. In-water sources will be controlled through the remedial actions identified in the FS process.

8.7.2 Decisions and Data Uses

As noted above, a decision must be made whether it is acceptable to proceed with remedial actions given the number, type, and concentration of sources present at the completion of the FS. Data needed are described below, and would be used in predictive modeling inputs to determine the potential for recontamination under various remedial alternatives. The RI will collect information on potential effects of ongoing sources to the river waters and sediments. This information will be referred to DEQ for further source investigations and controls as appropriate.

It is important to note that comparison of source levels to criteria or risk-based levels may be uninformative to understand the potential for recontamination and is probably an unacceptably simple approach. For example, it may be known that an outfall periodically exceeds water quality criteria, but this knowledge, by itself, does not indicate whether such discharges might cause settling of chemical constituents to the riverbed at concentrations that pose sediment-related risks.

8.7.3 Data Needs

Assuming that some type of predictive modeling is needed, data needs are determined by the model input requirements. In addition to these specific inputs, it is necessary to understand the general presence and location of potential upland sources along the riverbanks. Further, it is necessary to have a general understanding of the levels of chemicals and sediments that move into the ISA from upstream and downstream. This information will be useful to determine the location to run the model and at what spatial density.

The same natural attenuation model discussed above for Round 3 is also proposed for use to assess the potential for recontamination. Natural attenuation models predict changes in surface sediment chemistry given present understanding of water column, subsurface sediment, and groundwater sources. These models can also be used to predict changes in sediment chemistry that will occur after, for example, dredging or capping.

The data needs are the same as those described for natural attenuation. Given information on incoming sediment concentrations (see Natural Attenuation Studies section above), these models can be used to predict how the post-remediation cap surface or dredged surface chemical concentrations will change over time. If the post-remediation sediment surface reaches unacceptably high concentrations in the modeling, this provides valuable information that additional source controls need to be considered before such a remedial action should be undertaken. In addition, sufficient data must be available on the known or suspected sources so that where and at what density to model can be determined.

8.7.4 Recontamination Evaluation Tasks

The data collected for natural attenuation (as detailed in Appendix A, Attachment A4) in Round 3 will provide the basic inputs for the recontamination model, including:

- Grain size
- Surface chemical concentrations, water content, specific gravity
- Hydrodynamic modeling
- Sedimentation rates from radioisotope cores and/or sediment traps
- Settling sediment chemical concentrations from water column samples or sediment traps
- Mixed layer depth and mixing rate.

The modeling approach will use a one-dimensional fate and transport model that focuses on the sediment bed. As described in Appendix A, Attachment 4, the Boudreau model is currently proposed, but will described in greater detail in a modeling technical memorandum for EPA review and approval. The model predicts changes in chemical concentrations in the sediment bed given various chemical inputs (such as settling sediment) and outputs (such as diffusion and biodegradation). The data needs described above would be the primary information used to estimate these inputs and outputs. Thus, a future condition can be assumed (such as clean sediment surface after remediation) and existing and/or predictions of future chemical conditions of sources and the water column can be used to determine whether that clean sediment bed will recontaminate to unacceptable levels. Because the model is one-dimensional, it can be applied discreetly to various locations throughout the site to understand how recontamination potential might vary spatially.

Also, where groundwater is a known or suspected source (and/or flow of clean groundwater through impacted subsurface sediments is suspected), information on these sources and subsurface concentrations would be needed. This information may be available through LWG efforts, DEQ-directed efforts at individual upland sites, or a combination of both.

If the appropriate data are not available for any of these parameters, then the LWG will work with EPA to identify a process and method for obtaining the data, which may include: LWG data collection, data collection by individual upland site property owners, and/or data collection directed by DEQ on or near upland properties. However, Round 2 data collection described in Sections 6, 7.2, and 8.5 is intended to provide the vast majority of these data.

Where to model and at what density will be determined by available source effect information, which by Round 3 will likely include:

- LWG efforts to understand source effects to river waters and sediments (see Section 7.2)
- DEQ efforts to identify and control sources at individual sites
- EPA efforts regarding control of upstream sources.

It is difficult to predict the state of knowledge on all these sources at the time that Round 3 starts. Consequently, an exact program of sampling and analysis cannot be described at this time. However, the concept is to review the status and amount of source effect information and fill in data gaps, as needed, to provide sufficient information for recontamination modeling. This may include further sampling of sources that appear to be substantially contributing to in-water concentrations of chemicals of concern. While sampling of particular sources may be important to fill data gaps, direct measurements of in-water concentrations of chemicals is critical to making evaluations of recontamination potential. This might also include such studies as sediment traps near outfalls, water column samples near suspected sources, subsurface chemistry near sources, and sampling water quality in the Transition Zone near known or suspected groundwater sources. Again, any such data gaps will be filled in Round 3.

Although modeling summarized here and described more in Appendix A, Attachment 4, is intended to be the primary method of predicting potential future recontamination, other methods of data collection will be considered that might help directly verify recontamination potential. These may include characterization of potential areas that may erode and allow transport of chemicals downstream. This could also include examination of historical chemical concentration profiles in downstream areas with comparison to information on existing water column inputs. These and other data collection methods could be used to understand variations in potential long-term inputs in the model so that conditions sampled during Round 3 are not erroneously assumed to apply to all future conditions.

8.8 DEVELOPMENT, SCREENING, EVALUATION, AND SELECTION OF REMEDIAL ALTERNATIVES

The overall steps to the evaluation and selection of remedial alternatives is shown in Figure 8-1. As noted in Section 8.1, a range of remedial alternatives will be evaluated, including no action, institutional controls, *in-situ* containment, *in-situ* treatment, removal and disposal, removal and treatment. The steps of the FS process are generally prescribed by the SOW, and, to a lesser extent, by CERCLA guidance (EPA 1988) (see Appendix A). As outlined in Appendix A, the FS process results in series of alternative development reports that will be submitted to EPA (Figure 8-1). Appendix A currently describes this approach consistent with the linear process outlined in the SOW.

Wherever possible, some of the deliverables will be submitted simultaneously rather than in sequence. The most likely place to expedite the schedule is by simultaneous submittal of the following documents:

- Identify and Screen Remedial Technologies, Assemble and Document Alternatives, Screening Evaluation of Alternatives, and Alternatives Development and Screening summary reports
- Detailed Comparison of Alternatives Report and the Feasibility Study Report.

The process will be streamlined wherever possible, and the LWG is open to alternate ways of accelerating the above reports. Once agreement has been reached with EPA on how to schedule the FS deliverables, Appendix A will be revised to reflect this process.

In addition to the data needs identified by the previous tasks, some additional data on engineering properties of sediments and/or disposal sites in various areas may be needed in Round 3. These will generally include analyses like grain size, Atterberg limits, consolidation tests, and sheer tests. This information will be directly input into the evaluation of alternatives.

It should also be noted that this is the step in the FS process where remedial alternatives are screened and evaluated in detail per EPA (1998) guidance. This includes screening alternatives against the three primary criteria of effectiveness, cost, and feasibility, as well as detailed evaluation of alternatives against the nine CERLCA evaluation criteria of:

Threshold Factors:

- Overall protection of human health and the environment
- Compliance with ARARs

Primary Balancing Factors:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, and volume through treatment
- Short-term effectiveness
- Implementability
- Cost

Modifying Considerations:

- State acceptance
- Community acceptance.

For compliance of ARARs, a list of potential ARARs for the project have been compiled in Appendix A, Attachment 1. This includes regulations that address such potentially important issues as flooding and the affects of in-water work on aquatic resources. Thus, the remedial alternatives will need to have some early assessment of the magnitude of mitigation and its cost to run through the nine criteria evaluation.

8.9 FS REPORT

The FS report is the final deliverable under the AOC and describes the recommendation of the alternatives evaluation process and documents all the FS data collection, data evaluation, modeling, and engineering tasks. Appendix A describes the FS report in more detail. The purpose of this task is to present the recommended remedial alternatives to EPA and partners for review and approval, and finally, to assist in development of the proposed plan and ROD.

9.0 PROJECT MANAGEMENT PLAN

This project management plan describes the roles and qualifications of key personnel conducting the RI/FS for the Site. This plan also describes how the LWG will communicate and coordinate, both with EPA and among the LWG members (including the consultant team), the decision-making process and key decision points, project reporting requirements, schedule and schedule control, and cost control. A separate data management plan is provided in Appendix G.

9.1 PROJECT ROLES AND RESPONSIBILITIES

The overall project organization and major task responsibilities are illustrated in Figure 9-1. The RI/FS is being conducted by the LWG under the oversight of EPA, Region 10. Members of the LWG who are signatories on the AOC include:

- ATOFINA Chemicals, Inc.
- Chevron USA Inc.
- City of Portland
- Gunderson, Inc.
- Northwest Natural
- Oregon Steel Mills, Inc.
- Port of Portland
- Time Oil Co.
- ConocoPhillips Company (successor to Tosco Corporation)
- Union Pacific Railroad.

9.1.1 Agency Roles and Responsibilities

As described in the AOC and associated SOW, EPA is the lead agency for all in-water RI/FS activities and will oversee LWG activities associated with implementing the RI/FS. EPA will coordinate all Trustee, Tribe, and State of Oregon input with respect to development of technical and decision documents. At the completion of the RI/FS, EPA will select the remedy to be implemented at the Site. EPA will also oversee a public involvement process with input from the LWG. As stated in the SOW, EPA is the supporting agency for upland cleanup and source control activities. The site managers for EPA are currently Mr. Chip Humphrey and Ms. Tara Martich. A formal replacement for the EPA project manager designated in the AOC has not been made. All correspondence with EPA shall be sent to these individuals at the addresses listed in Table 9-1.

DEQ is the lead agency responsible for all upland cleanups and source control activities associated with the Site. In addition, DEQ is the support agency for the in-water RI/FS and will coordinate upland cleanup activities and decision-making with EPA. The lead contact for DEQ is Mr. Jim Anderson; his contact information is found in Table 9-1.

Trustee agencies and Tribes will review technical documents prepared under this AOC and will participate in technical meetings. Contact information for trustee and Tribal organizations is also presented in Table 9-1.

9.1.2 LWG Roles and Responsibilities

The LWG will conduct an RI/FS and report the results in documents according to the AOC and referenced EPA guidance. EPA has directed that negotiations on implementation of Early Actions be conducted outside the process covered by this Work Plan. Early Actions will be conducted under DEQ or EPA authority separate from work being performed under the AOC.

The LWG is co-chaired by Mr. Jim McKenna of the Port of Portland and Mr. Bob Wyatt of Northwest Natural. All official contact with the LWG should be through these co-chairs (see Table 9-1).

9.1.3 Consultant Team Roles and Responsibilities

The LWG consultant team is responsible for implementation of the RI/FS tasks at the direction and oversight of the LWG. Each team member is responsible for major RI/FS tasks reflecting their firm's areas of expertise. In turn, each firm will support other consultant team members where appropriate. Mr. Keith Pine of Integral Consulting, Inc. [formerly Striplin Environmental Associates (SEA)] will coordinate the RI/FS consultant activities and develop and implement the RI with support from Mr. Gene Revelas. Dr. Bill Williams and Ms. Laura Kennedy of Kennedy/Jenks Consultants are responsible for conducting the human health risk evaluation. Dr. Mike Johns and Ms. Lisa Saban of Windward Environmental will conduct the evaluation of ecological risks. Mr. Walt Burt of Groundwater Solutions will coordinate the groundwater tasks. Mr. Tom Schadt and Mr. Carl Stivers of Anchor Environmental will be responsible for the FS. Ms. Barbara Smith of Harris and Smith Public Affairs will provide public participation support for the project. Dr. David Ellis of Archeological Investigations Northwest will be responsible for coordinating the cultural resources work.

The consultant team effort will be augmented by use of experts in specific aspects of the RI/FS. These experts will be identified in work plans for specific sampling and analysis tasks.

Qualifications of the project managers for the consultant team are summarized below.

Mr. Keith Pine, a managing scientist with Integral Consulting, will manage the RI and coordinate the overall RI/FS efforts. In this role, he will oversee the RI technical work, participate in LWG strategic planning and agency negotiations, and coordinate RI/FS activities with the LWG consultant team and other technical consultants. Mr. Pine has 18 years experience in managing and providing oversight of sediment, soil, and groundwater investigations and cleanups at dozens of CERCLA, RCRA, and brownfields sites in the Pacific Northwest. An Oregon-registered geologist, he has managed multimedia RI/FS and RCRA facility investigations at several large facilities including an aerospace industrial site along the Lower Duwamish Waterway (Seattle), Frontier Hard Chrome (Vancouver), and Northwest Pipe and Casing (Clackamas).

Mr. Gene Revelas, a managing scientist at Integral Consulting, will provide assistance to Keith Pine in overall coordination of the RI/FS efforts and will also be the project's sampling and analysis coordinator. In these roles, he will assist in the coordination of RI/FS activities among the LWG consultant team and will oversee the efforts of Integral's field, laboratory coordination, and data analysis and evaluation project staff. Mr. Revelas has 18 years of technical and project management experience in the interpretation and regulatory use of aquatic environmental data with an emphasis on contaminated sediment site evaluations, dredged material characterizations, and open-water disposal site monitoring. He is an expert in the use of sediment-profile imaging for benthic habitat quality mapping and assessment. Mr. Revelas has directed sediment collection and data evaluation programs at complex contaminated sediment sites such as Hylebos Waterway in Commencement Bay (Tacoma) and the East Waterway in Seattle.

Dr. Bill Williams, a senior toxicologist and project manager at Kennedy/Jenks Consultants, will have primary responsibility for the human health risk assessment. Dr. Williams has over 19 years of experience conducting human health and ecological risk assessments. He has been instrumental in the development of new concepts to define cleanup strategies at contaminated sites, especially the conception and development of site-specific protective concentration levels. Protection concentration levels extend the results of risk assessments to bridge the gap between risk estimates and engineering cleanup strategies.

Ms. Laura Kennedy is a toxicologist and risk assessor at Kennedy/Jenks. Her experience in environmental consulting includes human health, ecological, and predictive risk assessments. She has conducted numerous risk assessments of industrial and residential sites and freshwater and riverine areas for both public and private sector clients. Recently, Ms. Kennedy conducted a series of human health and ecological risk assessments as components of voluntary cleanup actions. The risk assessments evaluated potential exposure to chemicals, including metals, PAHs, and PCBs in soil, water, and sediments.

Dr. Michael Johns, a principal of Windward Environmental, LLC, will serve as the ecological risk assessment manager. Dr. Johns is an aquatic scientist specializing in aquatic ecological risk assessments, particularly those associated with contaminated sediment. The emphasis of his 25 years of professional experience has been on the effects of toxic pollutants on aquatic organisms. Dr. Johns has managed RI/FS, NRDA, and other large multitask, multidisciplinary environmental investigations. His recent responsibilities include the Lower Duwamish Waterway RI/FS (Seattle), the East Waterway RI/FS (Seattle), the Grand Calumet River NRDA (Indiana), the Calcasieu Estuary Combined RI/FS and NRDA (Louisiana), and two Supplementary RIs at the Harbor Island Superfund Site in Seattle. Dr. Johns is a recognized expert on the use of bioassessment techniques to evaluate sediment contamination.

Ms. Lisa Saban, a senior scientist at Windward Environmental, LLC, will serve as Dr. John's ecological risk assessment project manager. Ms. Saban has served as a project manager or lead ecological risk assessor for numerous complex ERAs and sediment investigations over the last 12 years. She has managed and conducted environmental studies on the local, national, and international level, for both private and public sector clients. She has extensive experience negotiating in client-stakeholder interactions, managing complex ERAs, NRDA and injury evaluations, and directing oversight and review of sediment and water quality studies. She has been involved in numerous stakeholder groups as a lead sediment specialist and ecological risk assessor.

Mr. Walter Burt, a principal hydrogeologist at Groundwater Solutions, Inc., will serve as the technical lead for groundwater-related issues. Mr. Burt is a hydrogeologist with over 13 years of experience in conducting hydrogeologic studies in the Pacific Northwest. Much of his focus has been on groundwater characterization, groundwater supply, and contaminant fate- and transport-related projects in the lower Willamette Valley and Portland areas. Recent projects include site and regional hydrogeologic investigations involving assessment of groundwater/surface water interactions along the lower Willamette and Columbia rivers for construction, water supply, and contaminant transport and remediation purposes. He recently served as technical lead for the environmental oversight consultant team for the Willamette River West Side CSO project, project manager for the Phase 2 Deep Aquifer Yield Numerical Flow Model of the Portland Basin, and senior consultant to the Portland Water Bureau for groundwater technical services on the Columbia South Shore Wellfield.

Mr. Tom Schadt, a senior aquatic scientist and principal at Anchor Environmental, has 20 years experience in environmental consulting, including nationwide experience with sediment remediation. Mr. Schadt's major area of focus is shoreline redevelopment and cleanup projects, and investigation of water and sediment quality and biological effects. His sediment project experience includes CERCLA, state-led, and voluntary action sites. Much of his project management experience is with sediment management issues, including sediment characterization, FS development, cleanup design, long-term monitoring, and NRDAs. Tom has participated in sediment cleanup projects in both freshwater and marine environments, including rivers, lakes, bayous, estuaries, and bays.

Mr. Carl Stivers, a senior aquatic scientist at Anchor Environmental, has 15 years of consulting experience in sediment and water quality investigations. Past projects have included water quality impact evaluation, contaminated sediment investigation and remediation, and dredge sediment investigations. Mr. Stivers specializes in the management of complex environmental investigations particularly for sediment-related projects. Mr. Stivers has managed large-scale sediment remediation, water quality, and dredge disposal projects covering a wide range of sediment and water quality issues, including dredge and disposal impacts, sediment chemistry and toxicology, oceanographic studies, sediment risk assessments, benthic ecology, habitat restoration, NRDAs, chemical fate and transport modeling, sediment disposal site evaluation, and disposal suitability testing.

Ms. Barbara Smith is vice president and partner at Harris and Smith Public Affairs. She has more than 22 years of experience in journalism, government, and public affairs. Her work in environmental communications involves dozens of National Priorities List (NPL), Model Toxics Control Act (MTCA), Resource Conservation & Recovery Act (RCRA), Temporary Storage Depot, and Voluntary Cleanup Program sites, specializing in working with multi-PRP groups. She has facilitated several community advisory groups, participated in organizing local communities on behalf of site-specific communications, and has spoken on risk communication and environmental public involvement at many Pacific Northwest and national symposia. Harris and Smith Public Affairs has represented public and private sector clients throughout the Northwest from its Seattle-based office for more than 15 years.

Mr. David Ellis, M.P.A., a senior archaeologist at Archeological Investigations Northwest (AINW), will coordinate the cultural resources analysis. Mr. Ellis has directed cultural resource studies in the Portland area since 1976. He has been with AINW since 1990, serving as project manager for most AINW projects in the Portland area. Mr. Ellis has also served since 1992 as project manager for AINW's ethnographic and traditional cultural property studies. The latter experience included regular and frequent consultations and meetings with Tribal representatives. Mr. Ellis will supervise records search and data-gathering efforts, and represent AINW in team meetings and meetings with agencies and Tribes as needed. He will also be available for assistance and advice on Tribal coordination and consultation efforts.

9.2 COMMUNICATION AND COORDINATION

The complexity and duration of this project require a high level of organization and options for communications between EPA, EPA's partners, and the LWG, and among the members of each of those parties. In recognition of this complexity, several communications tools have been developed.

9.2.1 Shared Server

A collaborative web site has been established that allows selective access to project information, documents, and data. This web site is available to EPA, supporting agencies, members of the LWG and their respective consultants, and the RI/FS consultant team. Access requires a current web browser and an Internet connection, and access to the site is controlled via password.

Once users log in, the web site is organized into a series of tabular pages that provide viewable and downloadable announcements, the current calendar for project meetings, a user directory and contact list, and copies of the draft and final technical or decision documents. Validated data, maps, photos, and other information will also be made available on the web site. Tips for site use and information about changes to the site are posted on the home page. A search function is available to facilitate use of the site. Links to EPA and DEQ project web sites are also provided.

9.2.2 Meetings

In addition to electronic communications via the project web site, EPA and LWG technical and project management representatives meet on a regular basis, with the frequency of meetings depending on current project activities. Agenda are discussed and agreed upon in advance of each meeting. Either party can request a meeting or conference call to resolve specific issues in advance of scheduled meetings. Additional technical subgroup meetings between agency technical experts and managers and members of the consultant team and LWG are also used to foster additional discussion or develop details for an aspect of the RI/FS. As an example, the consultant team members in charge of the risk assessments met with EPA's toxicologists and risk assessors to discuss the risk assessment approach during preparation of the June 2002 RI/FS Work Plan. Similarly, technical subgroup meetings for groundwater, nature and extent, Early Actions, HHRA, and ERA have been conducted between agency technical experts and managers and members of the consultant team and LWG to facilitate resolution of issues and development of this Work Plan. Decisions on documents to be submitted to EPA or on how such documents should be drafted will only be made at meetings attended by LWG and EPA project managers.

9.3 DECISION-MAKING PROCESS

9.3.1 LWG Decision-making Process

The LWG will review data and information generated through implementation of this Work Plan consistent with the DQOs identified or refined throughout the RI/FS. The LWG consultant team will assist the LWG in interpretation of the data and information, and will make recommendations to the LWG for future RI/FS tasks or work products. The LWG will submit to EPA written recommendations regarding future RI/FS efforts.

9.3.2 EPA/DEQ/LWG Decision-making Process

Project decision-making is a cooperative process involving key technical and management staff from EPA, DEQ, and the LWG. Through frequent technical and management meetings, technical issues are discussed and evaluated, with the objective of reaching consensus on decisions.

EPA, DEQ, and the LWG hold regular project management meetings to discuss the agencies' technical and policy issues. These informal meetings provide an opportunity for the agencies and the LWG to raise issues pertaining to any aspect of the RI/FS and to strategize how best to address the issues. Agency project managers and members of the LWG project management team attend the project management meetings.

EPA and the LWG also have periodic formal technical meetings to discuss specific technical issues. The objective of these meetings varies. Some meetings are informational with the LWG providing data or recommended project approaches to EPA. In other meetings, EPA has the opportunity to provide the LWG with comments on technical approaches and documents.

Lastly, EPA, EPA's partners, and the LWG periodically hold informal *ad hoc* meetings and technical subgroup meetings during which technical experts have wide-ranging discussions of certain topics. The goal of these sessions is for both EPA and LWG technical experts to voice their opinions on technical issues. Principals from EPA and the LWG will attend *ad hoc* and technical subgroup meetings, although final resolution of technical issues is generally not a goal of these meetings.

9.3.3 Key Decisions

There are a number of key decisions that need to be made during the RI/FS, as well as any number of smaller decisions, that will focus the overall project.

Data Quality Objectives

EPA's (2000a) DQO process will be relied upon throughout the RI/FS to formulate the technical questions that will be addressed through field and/or literature studies.

EPA's 7-step DQO process will be applied prior to and following each data-gathering effort, including the compilation of historical data and field sampling programs, to identify outstanding data gaps and to make recommendations on any additional data-gathering activities that may be needed.

Risk Assessment Parameters

Numerous decisions must be made prior to submittal of the HHRA, ERA, and baseline risk assessment deliverables. For the ERA, decisions regarding assessment endpoints, receptors, exposure, models, and toxicological data and other issues will be made. For the HHRA, key issues include exposure scenarios, consumption rates, and toxicological data. These decisions are being made through a combination of informal *ad hoc*, subgroup, and formal technical meetings.

Preliminary Remedial Action Objectives

The development of preliminary RAOs is discussed in this Work Plan and Appendix A, Attachment A1. The preliminary RAOs are relatively broad statements of work that will be developed as additional information is gathered during the RI/FS. It is anticipated that the preliminary RAOs will developed at the start of the FS and final RAOs will be developed by the end of the FS process. The final RAOs will continue to be broadly defined statements of goals for the overall selected remedial alternative or combination of alternatives.

Field Sampling Plans

Decisions on field sampling plans will be made following application of the DQO process and identification of risk assessment parameters. The LWG will develop its proposed approach, including the types, numbers, and locations of samples, types of analyses, analytical requirements, and data reporting, for consideration by EPA. The LWG will revise these plans following receipt of comments from EPA.

Treatability Testing

As a step in the FS, a decision will need to be made regarding the need for treatability testing to develop further information regarding candidate treatment technologies, if any are identified. Treatability testing is complex and can involve a significant amount of time. The determination that treatability testing will be necessary should be made early in the overall RI/FS to allow time for such testing.

Identification of Potential Sediment Management Areas

A key decision will be the determination of potential sediment management areas (SMAs). Based on results of the baseline risk assessment, areas associated with unacceptable ecological or human health risk will be identified. These areas will be compared to other physical and site use areas to define SMAs. The FS will evaluate remedial alternatives for each SMA. EPA will decide on the cleanup action(s) that will be required for each SMA in its ROD.

Identification of Source Impacts to Site

Elements of sampling and analysis plans and data evaluations will be designed to understand how sources impact river sediments and waters. These include issues of upland sources, including groundwater, and sources entering the Site from upstream and downstream. Where this information indicates that sources are causing unacceptable risks to the Site, they will be referred to the appropriate agency for further investigation and, where appropriate, source controls. It is the LWG's understanding that DEQ is primarily responsible for investigating sources related to upland sites along the river, while EPA will be primarily responsible for investigating sources that are originating from upstream (or downstream) in the watershed. Further, the LWG understands that the RI/FS must include sampling and evaluations to understand source risks within the Site, but that the appropriate agencies are primarily responsible for identifying PRPs for those sources and enforcing appropriate actions by those parties.

9.4 REPORTING REQUIREMENTS

Required reporting includes monthly progress reports due to EPA on the 10th of each month, and the RI/FS technical reports provided in Table 9-2. Draft documents are to be provided to EPA according to the schedule presented in the AOC. Following receipt of draft documents, EPA will prepare written comments and provide them to the LWG. EPA has indicated that written comments will be provided no more than 30 days following receipt of a document.

Data, GIS products, maps, and/or photos will also be delivered to EPA, per the approved schedule and following the AOC requirements.

All draft and final technical documents will be posted to the project web site for agency review and comment, according to the deliverable dates outlined in the next section. Document content will follow EPA guidance for major deliverables such as the RI, baseline risk assessment, and FS.

As required by the AOC, deliverables will be sent by certified mail, return receipt requested, to the individuals listed in Table 9-1, the LWG co-chairs, and to any other addressees that EPA may designate in writing.

Monthly progress reports will describe activities conducted during the prior month; the preliminary results of any sampling, testing, or other data analysis performed during that period; the schedule for the next two months; and any problems or issues encountered, along with proposed resolutions.

9.5 SCHEDULE

The schedule for the RI/FS deliverables and tasks is provided in Table 9-2. Schedule control will be a very important task throughout the RI/FS. The goal of the EPA and the LWG continues to be conducting the RI/FS in an expedited manner. As such, the LWG frequently reviews work progress and associated schedules with the LWG consultants to ensure that the project is being completed as efficiently as possible. Schedule deviations may be requested to increase the overall efficiency of the program. For example, the schedule for this Work Plan was extended to allow for additional time for meetings with EPA and its project team to ensure that the work elements in the Work Plan met with EPA approval, thus reducing both EPA review time and the time needed for the LWG to revise and finalize the document.

There may be other instances when EPA and the LWG agree that a schedule revision is needed to resolve issues. If this occurs, the LWG will work with EPA to resolve the issues in a reasonable timeframe.

9.6 COST CONTROL

EPA and the LWG acknowledge that the RI/FS will be a complex and costly effort. However, EPA and the LWG also believe that the project can be completed cost-effectively. Elements of cost control include adhering to EPA's DQO process (EPA 2000a) to ensure that field studies focus on the collection of data that are necessary for the decision-making process, generating data that allow EPA and the LWG to focus on the most critical issues (e.g., sediment profile imaging to better understand physical transport), and the use of electronic deliverables whenever possible. These and other approaches will be used to control costs to the extent practical.

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11.0 GLOSSARY OF TERMS

A

Absorption: The uptake of water, other fluids, or dissolved chemicals by a cell or an organism (as tree roots absorb dissolved nutrients in soil).

Acceptable Levels: Levels of chemicals in media that do not cause unacceptable adverse risk to either ecological or human health receptors.

Adsorption: The process of adhering a chemical on the surface of a solid material as a chemical transport mechanism.

Alluvial: Relating to sediment deposited by flowing water.

Anthropogenic: Natural and human-made substances present in the environment as a result of human activities.

Aqueous: Composed of liquid water medium.

Aquifer: An underground geological formation, or group of formations, containing usable and practicably extractible quantities of water. Aquifers are sources of groundwater for wells and springs.

Assessment Endpoint: In ecological risk assessments, an explicit expression of the environmental value to be protected. It includes both an ecological entity and specific attribute thereof. For example, osprey are a valued ecological entity; reproduction and population maintenance of osprey, the attribute, form an assessment endpoint.

Attenuation: The process by which a compound is reduced in concentration over time, through absorption, adsorption, degradation, dilution, or transformation.

B

Background: Constituents or locations that are not influenced by the releases from a site, either naturally occurring or anthropogenic.

Bed Load: Sediment particles resting on or near the channel bottom that are pushed or rolled along by the flow of water.

Benthic Invertebrates: Organisms without vertebrae dwelling either in the sediment or on the sediment in streams and rivers.

Bioavailability: Degree of ability to be absorbed and ready to interact in organism metabolism.

Biota: The animal and plant life of a given region.

C

Carcinogen: Any substance that can cause or aggravate cancer.

Characterization of Ecological Effects: A step in the ecological risk assessment process that evaluates the ability of a stressor to cause adverse effects under given circumstances.

Characterization of Exposure: A step in the ecological risk assessment process that evaluates the interaction of a stressor with one or more receptors.

Cleanup: Actions taken to deal with a release or threat of release of a hazardous substance that could affect humans or the environment. The term "cleanup" is sometimes used interchangeably with the terms remedial action, removal action, response action, natural attenuation, or corrective action.

Columbia River Datum (CRD): A vertical datum established for the Columbia River from the lower river to the Bonneville Dam and on the Willamette from the Columbia up to Willamette Falls. At the Morrison Street bridge gauge, the CRD is 1.85 feet above NVGD29/47.

Combined Sewer Overflow: Discharge of a mixture of stormwater and domestic waste when the flow capacity of a sewer system is exceeded during rainstorms.

Community: In ecology, an assemblage of populations of different species within a specified location in space and time. Sometimes, a particular subgrouping may be specified, such as the benthic community in a river.

Confined Aquifer: An aquifer in which groundwater is confined under pressure that is significantly greater than atmospheric pressure.

Chemical(s) of Concern (COC): Chemicals identified through the baseline risk assessment that are judged to cause unacceptable adverse effects to human health and/or ecological receptors.

Chemical(s) of Interest (COI): Chemicals that have been detected at a site but have not been screened in the risk assessment process.

Chemical(s) of Potential Concern (COPC): Chemicals of interest that have been screened-in for evaluation in the risk assessment process.

D

Data Quality Objectives (DQOs): Qualitative and quantitative statements of the overall level of uncertainty that a decision-maker will accept in results or decisions based on environmental data. They provide the framework for planning and managing environmental data operations consistent with user's needs.

Dermal Absorption: Process by which a chemical penetrates the skin and enters the body as an internal dose.

Dermal Contact: Contact between a chemical and the skin.

Detection Limit: The lowest concentration of a chemical that can reliably be distinguished, with a stated level of confidence, from a zero concentration.

Dredging: Removal of mud and sediment from the bottom of water bodies.

E

Early Action: A non-time critical removal action pursuant to 40 CFR 300.415(b)(4).

Ecological Exposure: Exposure of a non-human organism to a stressor.

Ecological Risk Assessment: The application of a formal framework, analytical process, or model to estimate the effects of human actions(s) on a natural resource and to interpret the significance of those effects in light of the uncertainties identified in each component of the assessment process. Such analysis includes initial problem formulation, exposure and effects assessments, and risk characterization.

Ecosystem: The interacting system of a biological community and its non-living environmental surroundings.

Effluent: Wastewater--treated or untreated--that flows out of a treatment plant or industrial outfall. Generally refers to wastes discharged into surface waters.

Environmental Exposure: The interaction of a stressor with a human or ecological receptor.

Erosion: The removal of soil or sediment by wind or water.

Exposure Assessment: Identifying the pathways by which chemicals may reach receptors and estimating how much of a chemical an individual is likely to be exposed to.

Exposure Concentration: The concentration of a chemical interacting with the receptor.

Exposure Pathway: The path from sources of chemicals through environmental media to human or ecological receptors.

Exposure Route: The way a chemical enters an organism after contact (e.g., ingestion).

Exposure: The interaction of a stressor with a human or ecological receptor.

F

Flood Stage: A river stage established by the National Weather Service (NWS) above which flood damage may occur. The NWS defines flood stage for the Willamette River at Portland as 18.0 feet (datum unspecified).

G

Groundwater: Fresh water found beneath the earth's surface, usually in aquifers, that supplies wells and springs.

Groundwater Discharge: Groundwater entering surface water or exiting to the ground surface.

H

Habitat: The place where a population or community (e.g., human, animal, plant, microorganism) lives and its surroundings, both living and non-living.

Hazardous Substance: Any substance defined as a “hazardous substance” under CERCLA or ORS Chapter 465.

Hydraulic Gradient: In general, the direction of groundwater flow due to changes in the depth of the water table.

Hydrogeology: The geology of groundwater, with particular emphasis on the chemistry and movement of water.

I

Initial Study Area (ISA): The 5.7-mile stretch of the Willamette River from approximately the southern tip of Sauvie Island at river mile 3.5 to the southern end of Swan Island at river mile 9.2, and adjacent areas logically associated with an evaluation of the in-water portion of this stretch of the river. The ISA does not include upland sources of contamination being investigated or cleaned up pursuant to ORS 465 as implemented by the Oregon Department of Environmental Quality.

L

Light Non-Aqueous Phase Liquid (LNAPL): A non-aqueous phase liquid with a specific gravity less than 1.0. Because the specific gravity of water is 1.0, most LNAPLs float on top of the water table. Most common petroleum hydrocarbon fuels and lubricating oils are LNAPLs.

Lipid Solubility: The maximum concentration of a chemical that will dissolve in fatty substances. Lipid soluble substances are insoluble in water. They will very selectively disperse through the environment via uptake in living tissue.

Lowest Observed Adverse Effect Level (LOAEL): The lowest level of a stressor that causes statistically and biologically significant differences in test samples as compared to other samples subjected to no stressor.

M

Matrix: The sample material in which the chemicals of interest are found (e.g., water, sediment, tissue).

Mean High River Stage: The arithmetic mean of the maximum (e.g., highest daily measurement) observed river stage data in a given period (e.g., monthly mean high river stage).

Mean Sea Level (MSL): MSL is a tidal datum determined over a 19-year National Tidal Datum Epoch. It pertains to local mean sea level and should not be confused with the fixed datums of North American Vertical Datum of 1988 (NAVD88) or the National Geodetic Vertical Datum of 1929 (NGVD29). Data referencing MSL as the vertical datum in the Portland Harbor is technically on NGVD29/47.

Media: Specific environments such as air, water, soil that are the subject of regulatory concern and activities.

Mean High Water (MHW): A tidal datum. The average of all the high water heights observed over the National Tidal Datum Epoch (19-year period).

Mean Low Water (MLW): A tidal datum. The average of all the low water heights observed over the National Tidal Datum Epoch (19-year period).

Method Detection Limit (MDL): See *Detection Limit.*

Municipal Discharge: Discharge of effluent from wastewater treatment plants that receive wastewater from households, commercial establishments, and industries in the coastal drainage basin. Combined sewer/separate storm overflows are included in this category.

N

North American Vertical Datum of 1988 (NAVD88): This vertical datum is the national standard geodetic reference for heights. NAVD88 is a fixed datum derived from local mean sea level observations at Father Point/Rimouski, Quebec, Canada. NAVD88 replaced NGVD29/47 as the national standard geodetic reference for heights.

National Geodetic Vertical Datum of 1929 and Supplemental Adjustment of 1947 (NGVD29/47): NGVD29/47 is a fixed datum adopted and adjusted in 1947 as a national standard geodetic reference for heights prior to June 24, 1993 and is now considered superseded by NAVD88. NGVD29 is sometimes referred to as Sea Level Datum of 1929 or as **Mean Sea Level (MSL)** on some early issues of U.S Geological Survey topographic quads. NGVD 29 was originally derived from a general adjustment of the first-order leveling networks of the U.S. and Canada after holding mean sea level observed at 26 long-term tide stations as fixed. Historical data referencing MSL as the vertical datum in Portland Harbor is technically on NGVD29/47.

Naturally Occurring: Substances present in the environment in forms that have not been influenced by human activity.

Nature and Extent: Characterization of chemical distribution within a site.

No Observable Adverse Effect Level (NOAEL): An exposure level at which there are no statistically or biologically significant increases in the frequency or severity of adverse effects between the exposed population and its appropriate control. Some effects may be produced at this level, but they are not considered adverse or precursors to adverse effects.

No Observed Effect Concentration (NOEC): Exposure concentrations at which there are no statistically or biological significant differences in the frequency or severity of any effect in the exposed or control populations.

Non-Point Sources: Diffuse pollution sources (i.e. without a single point of origin or not introduced into a receiving stream from a specific outlet). The pollutants are generally carried off the land by stormwater.

O

Operable Unit: A discrete action that comprises an incremental step toward comprehensively addressing site problems. This discrete portion of a remedial response manages migration or eliminates or mitigates a release, threat of release, or pathway of exposure.

Ordinary High Water or High Water: Defined as the vegetation line or the line the water impresses on the soil by covering it for sufficient periods to deprive it of vegetation. It is established by field observation of seasonally high river levels by the U.S. Army Corps of Engineers and designates the jurisdictional limits of the Corps regulatory program. From Willamette RM 0 to 16, the ordinary high-water level ranges from 14.7 to 15.2 feet CRD (USACE 1991). The Oregon Division of State Lands defines the ordinary high water line (OHWL) as a line on the bank or shore to which high water ordinarily rises annually in season. The OHWL excludes exceptionally high-water levels caused by large floods (e.g., 100-year events).

P

Pathway: The physical course a chemical or pollutant takes from its source to the exposed organism.

Perched Water: Zone of unpressurized water held above the water table by impermeable rock or sediment.

Permeability: The rate at which liquids pass through soil or other materials in a specified direction.

Plume: A visible or measurable discharge of a contaminant from a given point of origin.

Point Source: A stationary location or fixed facility from which pollutants are discharged.

Population: A group of interbreeding organisms (i.e. members of the species) occupying a particular space; the number of humans or other living creatures in a designated area.

Porewater: Water extracted from the interstices of a sediment sample for water quality analysis or toxicity testing purposes.

Portland River Datum (PRD): Datum of reference plane from which river stage is measured on the Willamette River at Portland at the Morrison Bridge gauge. PRD equals 1.55 feet above NGVD29/47 or MSL, and the PRD gauge reports water levels 0.30 foot above CRD levels at this location.

Pre-AOC: Events including sampling and other studies that occurred prior to signing of the AOC for the Site.

Principal Threat: Those source materials considered highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur.

Q

Quality Assurance/Quality Control (QA/QC): A system of procedures, checks, audits, and corrective actions to ensure that all EPA research design and performance, environmental monitoring and sampling, and other technical and reporting activities are of the highest achievable quality.

R

Receptor: Human or ecological entity to be evaluated in a risk assessment.

Recharge Area: A land area in which water reaches the zone of saturation from surface infiltration (e.g., where rainwater soaks through the earth to reach an aquifer).

Recharge: The process by which groundwater is added to a zone of saturation, usually by percolation from the soil surface (e.g., the recharge of an aquifer).

Remedial Action (RA): The actual construction or implementation phase of a Superfund site cleanup that follows remedial design.

Risk: A measure of the probability that an adverse effect to human health or ecological receptors will occur as a result of a release of a hazardous substance.

Risk Assessment: Qualitative and quantitative evaluation of the risk posed to human health or the environment by the actual or threatened release of specific chemical(s).

Risk Characterization: The last phase of the risk assessment process that estimates the potential for adverse human or ecological effects to occur from exposure to a stressor and evaluates the uncertainty associated with the estimate.

Risk Estimate: A description of the probability that organisms exposed to a specific dose of a chemical will develop an adverse effect (e.g., cancer).

Risk Management: The process of evaluating and selecting alternative regulatory and non-regulatory responses to risk. The selection process necessarily requires the consideration of legal, economic, and behavioral factors.

Risk Reduction: Lessening the unacceptable risks from chemicals by lowering their concentrations, mobility, bioavailability, toxicity, or exposure to receptors.

River Stage: Height of a river measured relative to a datum or specific elevation.

Round 1: RI/FS field work performed during 2002. Initially termed Round 1A and Round 1 to denote separation of several months between sampling events.

Round 2: RI/FS field work proposed for after Round 1.

Round 3: RI/FS field work proposed for after the preliminary risk assessment is completed.

S

Saturated Zone: The area below the water table where all open spaces are filled with water under pressure equal to or greater than that of the atmosphere.

Silt: Sedimentary materials composed of fine or intermediate-sized mineral particles.

Solubility: The amount of mass of a compound that will dissolve in a unit volume of solution. Aqueous solubility is the maximum concentration of a chemical that will dissolve in pure water at a reference temperature.

Sorption: The action of soaking up or attracting substances.

Storm Sewer: A system of pipes (separate from sanitary sewers) that carries water runoff from buildings and land surfaces.

Stressors: Physical, chemical, or biological entities that can induce adverse effects on ecosystems or human health.

Surface Runoff: Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in surface depressions.

Surface Water: All water naturally open to the atmosphere (e.g., rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries).

T

Threshold: The lowest dose or concentration of a chemical at which a specified measurable effect is observed and below which it is not observed.

Transition Zone: The interval where both groundwater and surface water comprise some percentage of the water occupying pore space in sediments.

Trophic Levels: A functional classification of species that is based on feeding relationships.

Toxicity Testing: Biological testing (usually with an invertebrate, fish, or small mammal) to determine the adverse effects of a compound or effluent.

Toxicity: The concentration at which a substance or mixture of substances can cause adverse effects in humans or animals.

U

Unconfined Aquifer: An aquifer containing water that is not under pressure; and where the water level in a well is the same as the water table outside the well.

Unsaturated Zone: The area above the water table where soil pores are not fully saturated, although some water may be present.

Urban Runoff: Stormwater from urban environments including industrial, residential, commercial, vacant, and transportation land uses.

V

Vadose Zone: The zone between land surface and the water table within which the moisture content is less than saturation (except in the capillary fringe) and pressure is less than atmospheric. Soil pore space also typically contains air or other gases. The capillary fringe is included in the vadose zone.

Volatile: Any substance that evaporates readily.

W

Water Quality Criteria: Standards of water quality not to be exceeded under the Clean Water Act.

Weight of Scientific Evidence: Considerations in assessing the interpretation of published information about toxicity—such as quality of testing methods, size, and power of study design; consistency of results across studies; and biological plausibility of exposure-response relationships and statistical associations.

Willamette River Flood Stage: Defined as +18 feet CRD on the lower Willamette River.